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ASME-B40.1, "Gauges-Pressure Indicating Dial Type-Elastic Element," was adopted on October 3, 1994 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Commanding Officer, Naval Construction Battalion Center, Code 156, 1000 23rd Avenue, Port Hueneme, CA 93043-4301. DoD activities may obtain copies of this standard from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. The private sector and other Government agencies may purchase copies from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

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FSC 6685

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SPECIAL NOTICE

ASME B40.1-1991
GAUGES – PRESSURE INDICATING DIAL TYPE – ELASTIC ELEMENT

ASME B40.1-1991 was issued with misprints. A complimentary copy of the corrected version is enclosed. Please discard the original issue.

We apologize for any inconvenience.

MAY 1992

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
345 East 47th Street, New York, N.Y. 10017

K1591N

ASME B40.1-1991
(REVISION OF ANSI/ASME B40.1-1985)

Gauges — Pressure Indicating Dial Type — Elastic Element

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Gauges — Pressure Indicating Dial Type — Elastic Element

ASME B40.1-1991

(REVISION OF ANSI/ASME B40.1-1985)

The American Society of Mechanical Engineers

345 East 47th Street, New York, N.Y. 10017

Date of Issuance: September 27, 1991

This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda or written interpretations of the requirements of this Standard issued to this Edition.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Consensus Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment which provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

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FOREWORD

(This Foreword is not part of ASME B40.1-1991)

ASME Standards Committee B40 is comprised of a balanced cross section of pressure gauge users, manufacturers, and interested members representing governmental agencies, testing laboratories, and other standards producing bodies. All are convinced that national standards such as this one serve not only to provide product performance and configuration guidelines, but also to inform and update the specifier and user regarding the science of pressure gauge production, application, and use. The standards are vehicles by which the Committee as a body can transmit to users the benefits of their combined knowledge and experience as regards the proper and safe use of pressure gauges.

The Committee, in its continual effort to make the B40.1 pressure gauge standard more informative and comprehensive, has scrutinized this document and has made the following additions and improvements:

(a) all definitions, previously listed in both the main document and the Appendix, have been combined;

(b) certain new definitions have been added;

(c) pressure equivalents of sea water, and water at 60°F have been added;

(d) paragraphs related to Insatllation, Vibration Failure, and Vibration-Induced Failure have been added;

(e) Accuracy Test Procedure has been clarified;

(f) Liquid Filled Gauge Test added;

(g) Case – Slow Leak Test added;

(h) listing of referenced documents was removed because of an ASME ruling that would automatically accept all referenced documents as U. S. Standards. This was not our intent when these references were included, and is beyond the scope of this Committee.

The formulation and approval of this Standard did not include the investigation or consideration of patents. Neither ASME nor the B40 Committee shall be responsible for identifying applicable patents or for conducting inquiries into the legal validity or scope of those patents brought to their attention. Prospective users of this Standard are responsible for protecting themselves against any patent infringement liability.

This Standard is advisory only. Its use is entirely a voluntary matter and shall in no way preclude the manufacture or use of products that do not conform. Neither ASME nor the B40 Committee assumes responsibility for the effects of observance or nonobservance of recommendations made herein.

This Standard was approved by the B40 Standards Committee and approved as an American National Standard by the American National Standards Institute of January 14, 1991.

ASME STANDARDS COMMITTEE B40
Specifications for Pressure and Vacuum Gauges

(the following is the roster of the Committee at the time of approval of this Standard.)

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GAUGES – PRESSURE INDICATING DIAL TYPE – ELASTIC ELEMENT

1 SCOPE

This Standard is confined to analog, dial-type gauges, which, utilizing elastic elements, mechanically sense pressure and indicate it by means of a pointer moving over a graduated scale.

It does not include gauges of special configuration designed for specific applications, edge reading, deadweight or mercury floated piston gages, or any other gauges not utilizing an elastic element to sense media pressure.

2 PRESSURE GAUGES, GENERAL

2.1 Pressure Defined

See Fig. 1.

2.2 Pressure Gauge Components

See Fig. 2.

2.3 Pressure Gauge Terminology Defined

absolute pressure – see *pressure, absolute*

absolute pressure gauge – see *gauge, absolute pressure*

accuracy – the conformity of a gauge indication to an accepted standard or true value. Accuracy is the difference (error) between the true value and the gauge indication expressed as a percent of the gauge span. It is the combined effects of method, observer, apparatus, and environment. Accuracy error includes hysteresis and repeatability errors, but not friction error. It is determined under specific conditions.

accuracy, reference – the accuracy of a gauge under reference conditions [normal position at 73.4°F (23°C) and 29.92 in. Hg barometric pressure]

adjustment, pointer – a means of causing a change in indication. The change is approximately equal over the entire scale. Some examples of this type of adjustment are adjustable pointers, rotatable dials, rotatable movements, and other similar items. This adjustment, if provided, is generally accessible to the gauge user (see para. 6.2.3.4).

adjustment, span – a means of causing a change in the angle of pointer rotation for a given change in pressure. This adjustment is not generally accessible to the gauge user.

ambient pressure – see *pressure, ambient*

bar – a metric pressure unit equivalent to 14.50 psi

bellows – a thin walled, convoluted elastic pressure sensing element (see Fig. 3)

bezel – see *ring*

Bourdon tube – a tubular elastic pressure sensing element. May have "C," helical, spiral or other form (see Fig. 3).

brazing – a metal joining process wherein coalescence is produced by use of nonferrous filler metal having a melting point above 800°F (425°C), but lower than that of the base metals joined

calibration – the process of graduating the pressure scale or adjusting the mechanism to cause the gauge to indicate within specified accuracy limits

calibration verification – the checking of a gauge by comparison with a given standard to determine the indication error at specified points of the scale

case ring – see *ring, cam*

case – the housing or container that supports, protects and surrounds the internals

case, liquid filled – a case that is filled with a liquid such as glycerine or silicone fluid to a least 75% of its total internal volume. Liquid filled cases may be either open front or solid front types. The purpose of this construction is to protect the internals from damage caused by severe vibration of pulsation or to exclude ambient corrosives, or both.

case, open front with case pressure relief – a case with a pressure relief device or openings and no partition between the pressure element and the window (see Fig. 4). An alternate construction is a plastic window especially designed to relieve internal case pressure.

case, open front without case pressure relief – a case having no partition between the pressure element and the window, and no pressure relief devices or openings (see Fig. 4)

case, pressure tight – a case capable of maintaining a pressure differential between the inside and the outside of the case

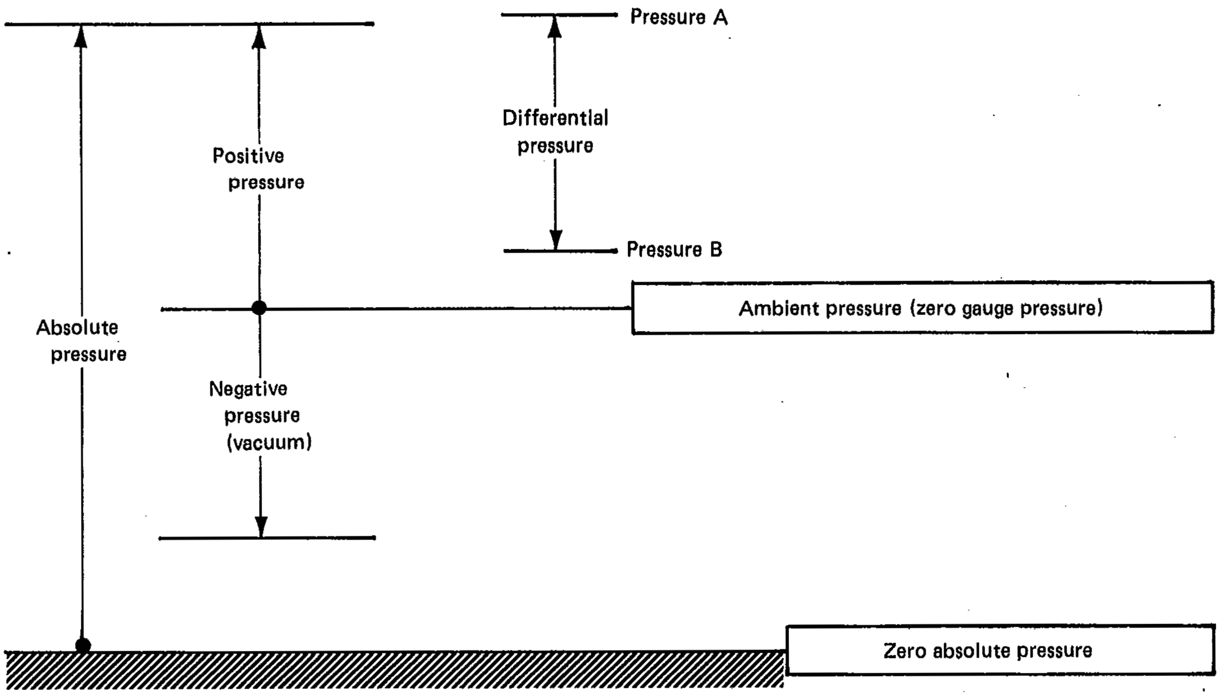


FIG. 1 BASIC PRESSURE TERMS

case, sealed – a case which is sealed to exclude ambient corrosives

case, size – see *size, gauge*

case, solid front with pressure relief back – a case having a partition with minimum opening(s) between the pressure element and the window, and a pressure relieving back. The partition may be an integral part of the case (see Fig. 4).

column, liquid – see *liquid column*

compound gauge – see *gauge, compound*

conditions, environmental – the conditions external to the gauge, including weather, temperature, humidity, salt spray, vibration, corrosive atmosphere, and other similar conditions that could affect the performance of the gauge

conditions, extreme operating – the limits of the environmental conditions within which the instrument may be operated. Under these conditions, the stated accuracy does not necessarily apply.

conditions, normal operating – the environmental conditions in which the stated accuracy applies

correction – the quantity that is algebraically added to an indicated value to obtain the true value. The algebraic sign of the correction is opposite to the sign of the error.

corrosion failure – see *failure, corrosion*

creep – a progressive change in indication with constant applied pressure, under the same environmental conditions. It is usually expressed as a percentage of span per unit of time.

crystal – see *window*

dead weight tester – a pressure testing device by which very accurate known pressures can be generated by means of a pressure source and a piston gauge

dial – the component that contains the scale and nomenclature

dial, dual scale – a dial indicating pressure in terms of two different units of measure, on concentric arcs, such as kPa and psi. One example of the many different types in common use is illustrated.

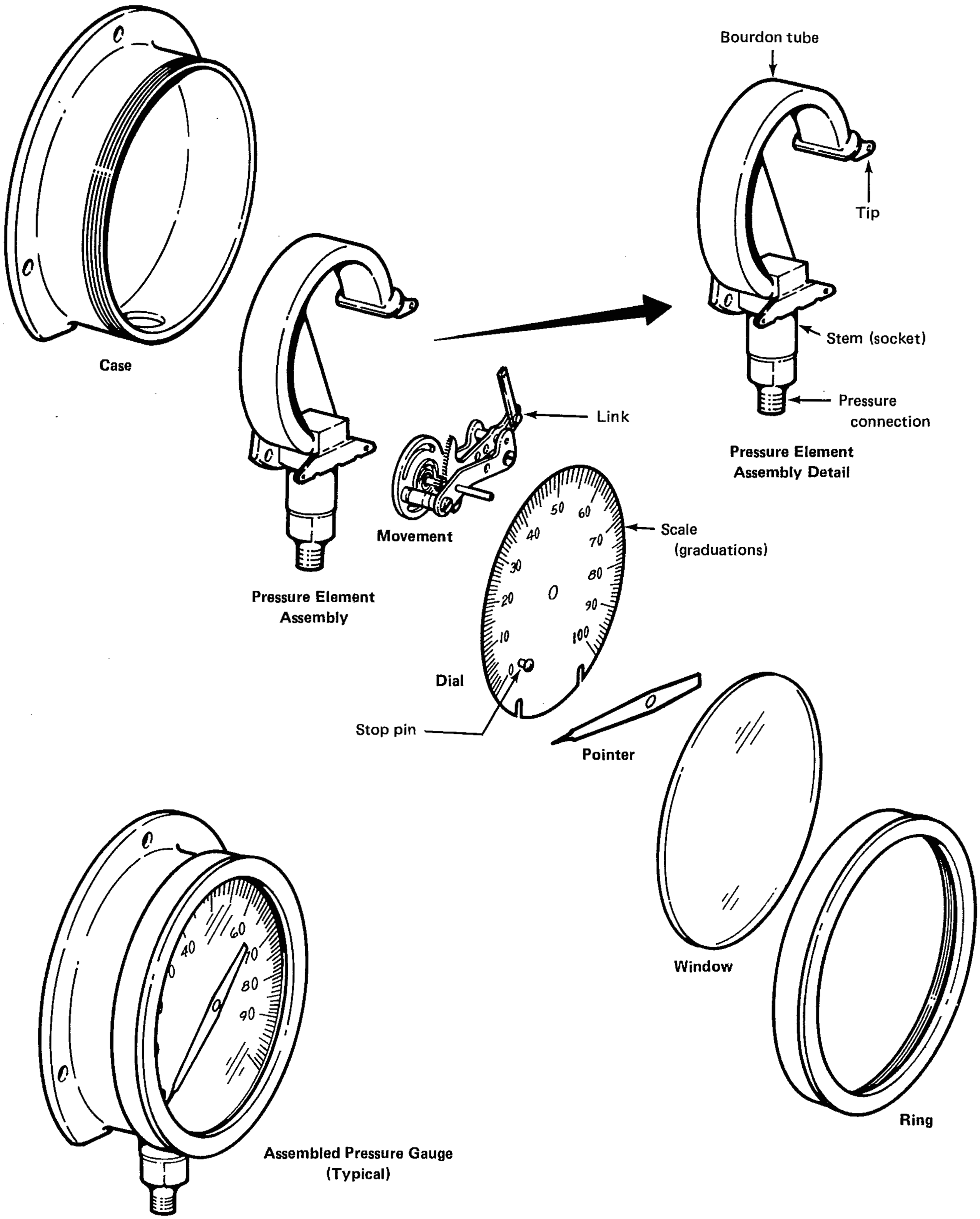
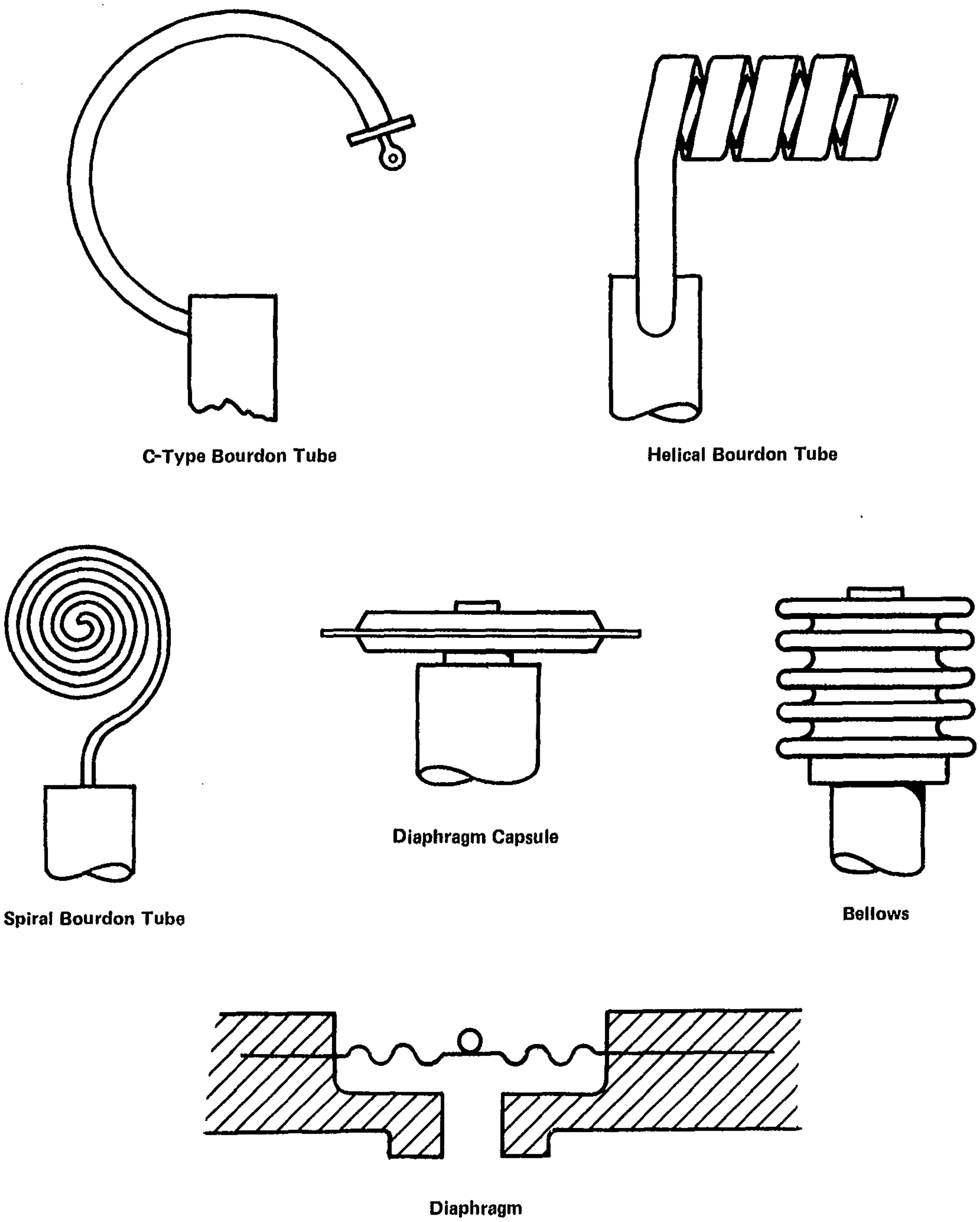
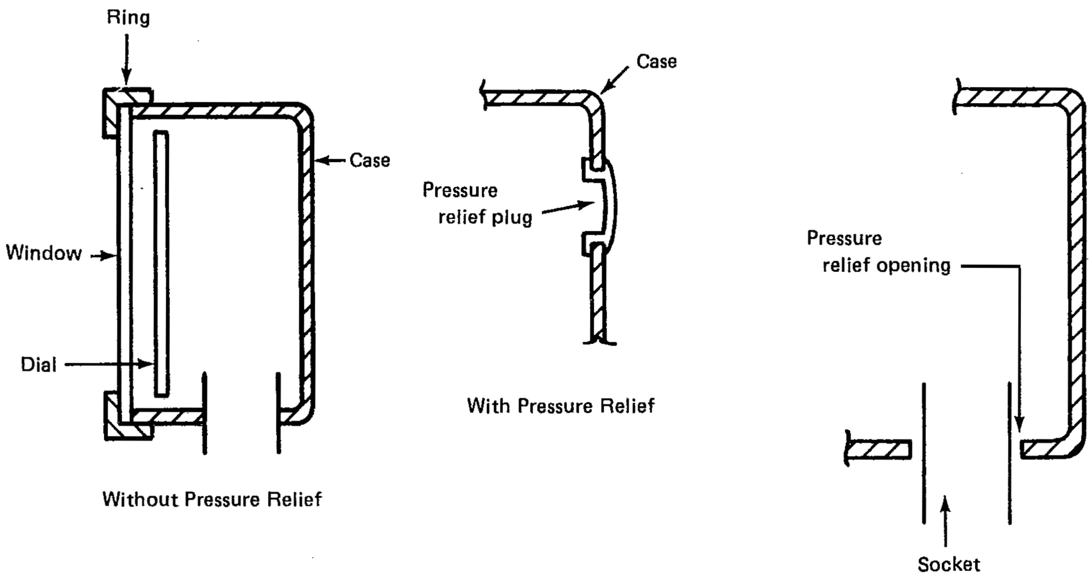


FIG. 2 PRESSURE GAUGE COMPONENTS (C TYPE BOURDON ILLUSTRATED)

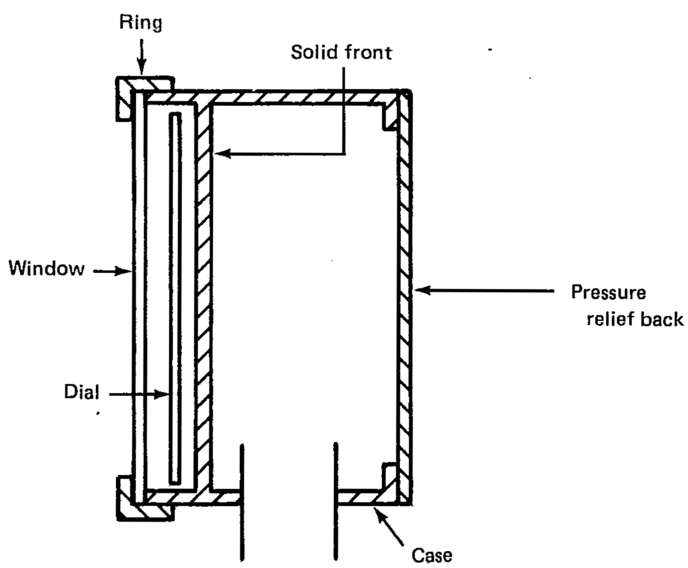


GENERAL NOTES:
(a) The above diagrams are schematic and not intended to show design detail.
(b) The above diagrams are various types of elastic elements used in pressure gauges.

FIG. 3 ELASTIC ELEMENTS



(a) Open Front

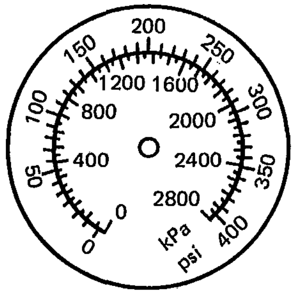


(b) Solid Front With Pressure Relief Back

GENERAL NOTE: The above diagrams are schematic and not intended to show design details.

FIG. 4 CASES

EXAMPLE:



dial graduations – the individual division marks of the scale that indicate pressure magnitude

dial, mirror – a dial with a reflector band adjacent to the scale for the purpose of reducing reading-parallax errors

dial nomenclature – see *nomenclature, dial*

diaphragm – an elastic element in the form of a single flat or convoluted plate that deforms to provide displacement in response to a change in pressure differential across it (see Fig. 3)

diaphragm capsule – an elastic element comprised of two convoluted diaphragm plates jointed to form a capsule of pressure container that expands and contracts in response to a change in pressure differential across the plates. Diaphragm capsule elements may have one or more capsules to provide appropriate displacement (see Fig. 3).

differential gauge – see *gauge, differential*

differential pressure – see *pressure, differential*

duplex gauge – see *gauge, duplex*

elastic element – see *element, elastic*

element, elastic – the elastic component of the pressure element assembly that moves in response to pressure changes. It may be a Bourdon tube, bellows, diaphragm, or other type of member (see Fig. 3).

element assembly, pressure – the assembly, including the elastic element, that converts a pressure change into motion. It may also include a stem, tip, restrictor, and other components (see Fig. 2).

environmental conditions – see *conditions, environmental*

error – the difference between the indicated value and the true value of the variable being measured. A positive error denotes that the indicated value is greater than the true value (see also *correction*).

error, fatigue – the change of pressure indication that results from repeated applications of stress (pressure cycles). It is expressed as a percentage of span, number of cycles, and minimum and maximum values of pressure cycles.

error, friction – the difference between indicated readings before and after the gauge has been lightly tapped

error, hysteresis – the difference between increasing pressure and decreasing pressure readings at any point on the scale obtained during a pressure cycle after friction errors have been eliminated by tapping (see para. 6.2.3.3 and Fig. A1)

error, offset – the error exhibited when the elastic element is unpressurized. It is expressed as a percentage of span (see Fig. A1).

error, position – the change of pressure indication that results when the gauge is placed in a position different from that in which it was calibrated

error, span – the error exhibited when the input is at maximum scale pressure minus the error exhibited when the input is at minimum scale pressure. It is expressed as a percentage of span.

error, temperature – the change of pressure indication that results when the gauge components are at a temperature different from their temperature at calibration

explosive failure – see *failure, explosive*

extreme operating conditions – see *conditions, extreme operating*

failure, corrosion – elastic element failure resulting from corrosive chemical attack on the element walls (see para. 4.2.7.3)

failure, explosive – elastic element failure caused by the release of explosive energy generated by a chemical reaction inside the element (see para. 4.2.7.4)

failure, fatigue – elastic element failure resulting from repeated applications of stress (see para. 4.2.7.1)

failure, overpressure – elastic element failure caused by the application of internal pressure (positive or negative) in excess of the rated pressure of the element (see para. 4.2.7.2)

failure, overtemperature – failure as a result of continuous exposure to high ambient temperature

failure, thermal shock – failure as a result of repeated, rapid exposure to ambient temperature extremes

fatigue failure – see *failure, fatigue*

fiber – any nonmetallic, flexible, threadlike contaminant with a length-to-diameter ratio of at least 10

flush mounted – see *gauge, flush mounted*

friction error — see *error, friction*

friction ring — see *ring, friction*

ft H_2O — see para. 3.3.2.1

full scale pressure — see *pressure, full scale*

gage, piston — a device that indicates the presence of a predetermined pressure by means of weights loaded on an effective area such as a floating piston or a ball (see para. 6.1.1.1)

gauge, absolute pressure — a gauge that indicates absolute pressure (see para. 3.4.1.11)

gauge, acetylene — see para. 4.3.8.2

gauge, ammonia — see para. 4.3.8.3

gauge, chemical — see para. 4.3.8.4

gauge, compound — a gauge that indicates both positive and negative gauge pressure (see para. 3.4.1.8)

gauge, differential — a gauge having two pressure connections and a pointer, which indicates the difference between two applied pressures

gauge, duplex — a gauge having two pressure connections and two pointers, which indicate two applied pressures simultaneously

gauge, flush mounted — a gauge provided with supporting means on the case so that it may be set through a hole in a panel. When installed, the dial is approximately flush with the panel (see Fig. 5).

gauge, hydraulic — a gauge designed to indicate the pressure developed in hydraulic systems. It may be equipped with a protective means to prevent damage to the internals in the event of a sudden pressure release.

gauge, liquid filled — a gauge in which the case is filled with a liquid (see *case, liquid filled*)

gauge, liquid level — a gauge with a dial graduated in units of head heights, such as feet (meters) of water

gauge, oxygen — see para. 4.3.8.5

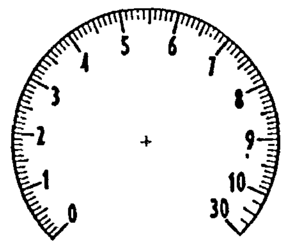
gauge, pressure — a device that senses and indicates pressure using ambient pressure as datum (zero)

gauge, receiver — a gauge designed to indicate the output signal from a pneumatic transmitter. It is calibrated in terms of the transmitter output. The dial may be graduated in units of pressure, temperature, flow, or other measurements corresponding to the transmitter input.

gauge, refrigerant — a gauge with a dial graduated in units of pressure and equivalent saturation temperature for refrigerant(s) other than ammonia

gauge, retard — a gauge having a scale that is compressed at one or both ends (see para. 3.4.1.6). One example of the many different types in common use is shown.

EXAMPLE:



Scale shown is retarded from 10 to 30

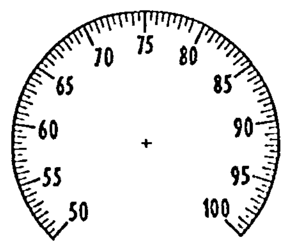
gauge, single — a gauge having one pressure connection and one pointer, which indicates one applied pressure

gauge, specific service — a gauge designed for a specfic service, such as indicating the pressure of explosive, corrosive, or viscous media (see para. 4.3.8)

gauge, stem (socket) mounted — a gauge supported by attachment at the stem (socket) pressure connection (see Fig. 5)

gauge, suppressed scale — a gauge having a scale that starts at some value appreciably above zero (see para. 3.4.1.7). One example of the many different types in common use is shown.

EXAMPLE:



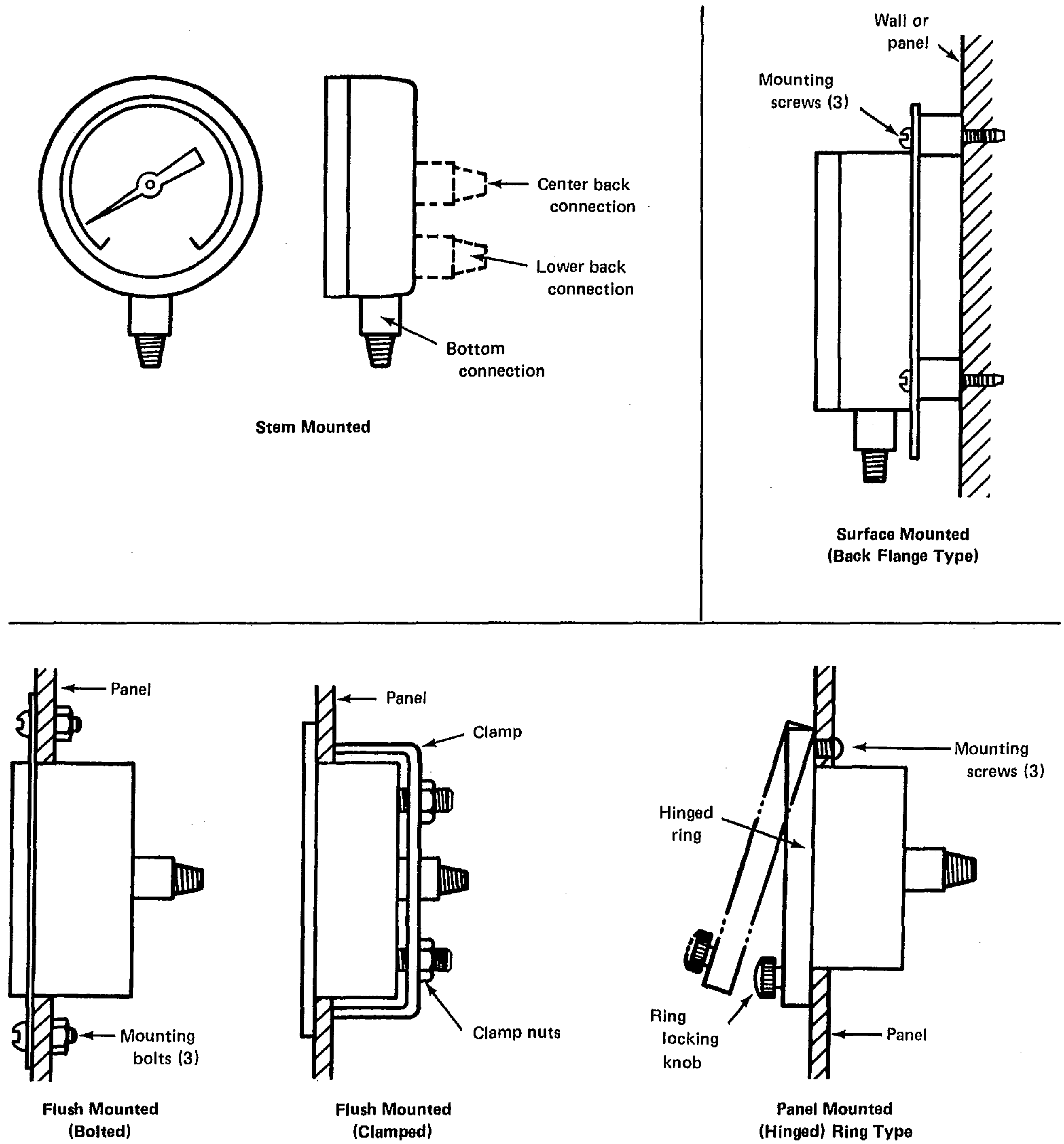
Scale shown is suppressed 0 to 50

gauge, surface (wall) mounted — a gauge whose case can be mounted to a wall or flat surface

gauge, temperature compensated — a gauge that is compensated to reduce errors caused by operation at ambient temperatures other than that at which it was calibrated

gauge, test — a gauge used to check the accuracy of other gauges or pressure actuated devices. The test gauge has an accuracy significantly better than the device being tested.

gauge, vacuum — a gauge that indicates negative gauge pressure (vacuum)



GENERAL NOTES

(a) These diagrams are schematic and not intended to show design details.

(b) Surface and flush mounted cases may also be stem mounted.

FIG. 5 CASES/MOUNTING

graduations, dial — see *dial, graduations*

grommet — see *plug, pressure relief*

H_2O — water

Hg — mercury

hydraulic gauge — see *gauge, hydraulic*

hysteresis error — see *error, hysteresis*

in. H_2O — see para. 3.3.2.1

in. Hg — see para. 3.3.2.1

internal stop — see *stop, internal*

kg/cm^2 — see para. 3.3.2.1

kPa — see para. 3.3.2.1

lens — see *window*

life, fatigue — the number of pressure cycles beyond which leakage of the pressure element assembly may occur. Accuracy may be degraded even if leakage has not occurred (see *error, fatigue*).

link — the component that connects the elastic element to the movement

liquid column — a pressure measuring device employing a column and reservoir of liquid (oil, water, mercury, or other liquid). Pressure indicated by the height of the liquid column, measured at the miniscus.

liquid filled case — see *case, liquid filled*

liquid filled gauge — see *gauge, liquid filled*

liquid level gauge — see *gauge, liquid level*

manometer — see ASME/ANSI PTC 19.2, Pressure Measurement

medium — the process fluid (gas of liquid)

mirror, dial — see *dial, mirror*

mounting — the means by which the gauge is installed or supported

mounting, flush — see *gauge, flush mounted*

mounting, gauge — see *mounting*

mounting, stem socket — see *gauge, stem (socket) mounted*

mounting, surface (wall) — see *gauge, surface (wall) mounted*

movement — the gauge component that converts pressure element motion to rotary pointer motion

NBS — National Bureau of Standards (see NIST)

negative pressure (vacuum) — see *pressure, negative*

NIST — National Institute of Standards and Technology (formerly NBS)

nomenclature, dial — may include, but is not restricted to, the following: materials of wetted parts, restricted application notices such as USE NO OIL, and presence of special features such as an internal stop

normal operating conditions — see *conditions, normal operating*

NPT — American Standard taper pipe threads. Defined by ANSI B1.20.1, Pipe Threads (Except Dryseal).

operating pressure — see *pressure, operating*

overpressure — the application of a pressure beyond the full scale pressure

overpressure failure — see *failure, overpressure*

Pa — see para. 3.3.2.1

particle — any solid contaminant other than fiber

pascal — see para. 3.3.2.1

piston gage — see *gage, piston*

plug, pressure relief — a plug inserted in the gauge case wall that, in the event of an element leak, vents, minimizing case pressure buildup

pointer — the component that, in conjunction with the dial, indicates pressure

pointer adjustment — see *adjustment, pointer*

position error — see *error, position*

positive pressure — see *pressure, positive*

pressure, absolute — a pressure using zero absolute pressure as datum (see Fig. 1)

pressure, ambient — the pressure surrounding the gauge, usually atmospheric (barometric) pressure (see Fig. 1)

pressure, burst — see *pressure, rupture*

pressure, differential — the difference between two pressures (see Fig. 1)

pressure element — see *element assembly, pressure*

pressure, full scale — the highest numerically defined graduation on the unretarded portion of the scale

pressure, gauge — a positive pressure (greater than ambient) or negative pressure (less than ambient) using ambient pressure as datum (see Fig. 1)

presure gauge — see *gauge, pressure*

pressure, negative (vacuum) — gauge pressure less than ambient pressure using ambient pressure as datum (see Fig. 1)

pressure, operating — the pressure at which a gauge is normally operated

pressure, positive — gauge pressure greater than ambient pressure (see Fig. 1)

pressure, process — the pressure of the process medium at the pressure connection of the sockets

pressure, proof — the maximum pressure a gauge can withstand without evidence of change in accuracy. Proof pressure may be a semidestructive test and

should not be conducted repeatedly on the same gauge. It may be expressed as a pressure or as a percentage of full scale.

pressure, rated — full scale pressure unless otherwise specified

pressure relief plug — see *plug, pressure relief*

pressure, rupture — the maximum pressure above which the pressure element assembly may no longer hold pressure

pressure, variable — pressure that increases or decreases, or both, at a rate greater than that allowed for steady pressure; may include hight pressure, short duration impulses (pressure spikes)

psi — see para. 3.3.2.1

psia — see para. 3.3.2.1

psid — see para. 3.3.2.1

psig — psi (see para. 3.3.2.1)

radius, turning — see Fig. 6

range — the high and low limits of the scale (including retarded portions) expressed in the sequences and units in which they occur. For example: 0/100 kPa, 200/500 psi, 30 in. Hg vac/30 psi.

readability — the uncertainty inherent in the observer's ability to determine the indicated pressure value. Factors that may affect readability include length of scale, graduation configuration and spacing, pointer design and width, parallax, distance between observer and scale, illumination, stability of pointer, pointer and scale colors and the liquid level line in liquid filled gauges.

receiver gauge — see *gauge, receiver*

refrigerant gauge — see *gauge, refrigerant*

repeatability — the maximum difference between a number of consecutive indications for the same applied pressure under the same operating conditions, approaching from the same direction, after lightly tapping the gauge. It is usually expressed as a percentage of span.

resonance — resonance of a system forced oscillation exists when any change, however small, in the frequency of excitation causes a decrease in the response of the system. (A resonance may occur in an internal part of the gauge, with no outward manifestation.)

restrictor — the device that restricts fluid flow between the pressure source and the pressure element. It is used to reduce the effect of pressure fluctuations or to control flow from a pressure element that has failed in service, or both. It may be integrally mounted or seperate from the gauge.

retard gauge — see *gauge, retard*

ring — the component that secures the window to the case. Ring configurations will vary for design and aesthetic reasons.

ring, cam — a ring similar to the threaded ring except that the threads are replaced by a cam arrangement

ring, friction — a ring retained by means of an interference or friction fit between it and the case

ring, hinged — a ring retained by a hinge-type device and a single retaining screw

ring, slip — a ring similar to the friction ring except that it has a clearace fit with the case and is secured by screws

ring, snap — a ring that snaps into a groove on the case

ring, threaded — a ring having threads that match threads on the case

scale — markings on the dial, consisting of graduations, related numerals, and units of measure

sealed case — see *case, sealed*

shock (impact) resistance — the maximum deceleration a gauge can withstand without damage or evidence of a change in accuracy of more than a specified value. It is expressed in g's, time duration (10% to 90% of the leading edge of the shock pulse), and number of impacts.

significant surface — see *surface, wetted*

silver brazing — brazing using a nonferrous filler metal containing silver

single gauge — see *gauge, single*

size, gauge — the nominal size of a gauge. Approximately the inside diameter of the case, in inches, at the dial.

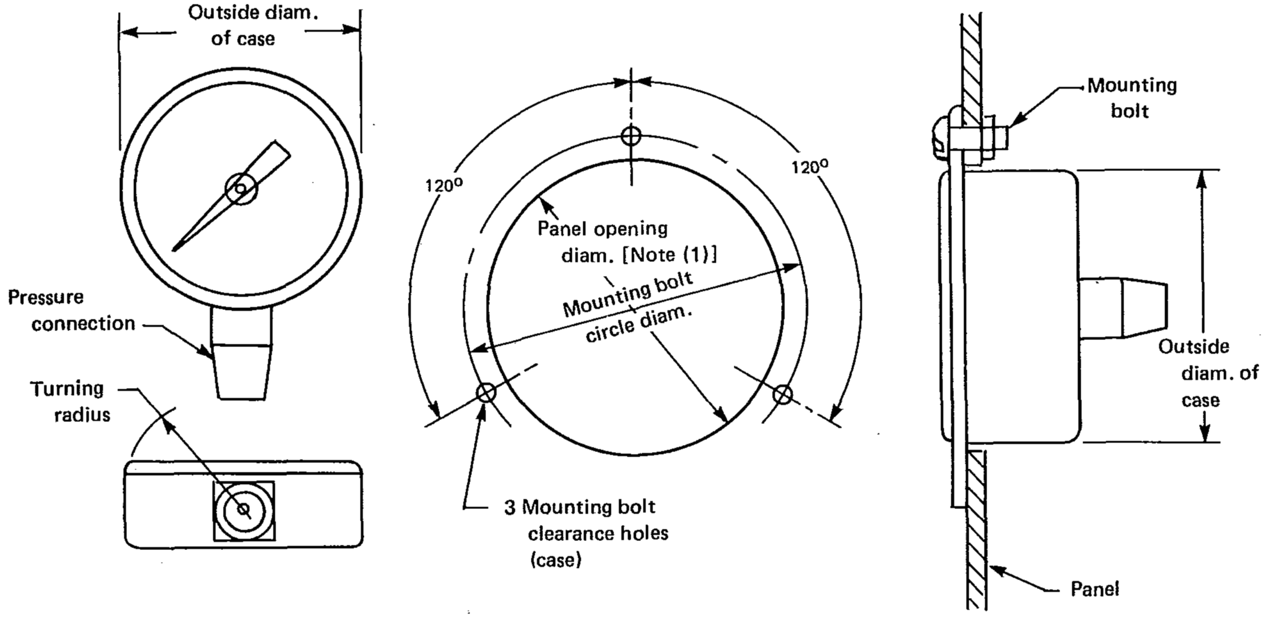
slip ring — see *ring, slip*

snap ring — see *ring, snap*

socket — see *stem*

soft soldering — see *soldering*

soldering (soft soldering) — a metal joining process wherein coalescence is produced by heating to suitable temperatures and by using a nonferrous alloy fusible at temperatures below 800°F (425°C) and having a melting point below that of the base metals being joined



Gauge Size	Flush/Surface Mounting Dimensions								Stem Mounted	
	Mounting Bolt Circle Diam.		Case Bolt Hole Diam.		Panel Opening Diam.		Outside Diam. of Case, Max. [Note (1)]		Turning Rad, Max.	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1½	1.91	48.5	0.13	3.4	1.65	41.9	1.59	40.4	1.13	28.7
2	2.56	65.0	0.16	4.5	2.19	55.6	2.13	54.1	1.44	36.6
2½	3.13	79.5	0.16	4.5	2.81	71.4	2.75	69.9	1.69	42.9
3½	4.25	108	0.22	5.6	3.81	96.8	3.75	95.3	2.38	60.5
4½	5.38	137	0.22	5.6	4.94	125	4.88	124	...	...
6	7.00	178	0.28	7.1	6.50	165	6.44	164	...	...
8½	9.63	245	0.28	7.1	9.00	229	8.94	227	...	...
12	13.50	343	0.28	7.1	12.62	321	12.56	319	...	...
16	17.00	432	0.28	7.1	16.50	419	16.44	418	...	...

GENERAL NOTE: See para. 7.3 for SI (DIN) case sizes.

NOTE:
(1) Flush mounted cases only.

FIG. 6 RECOMMENDED CASE AND MOUNTING DIMENSIONS

span — the algebraic difference between the limits of the unretarded portion of the scale.

The span of a 0/100 kPa gauge is 100 kPa.

The span of a *suppressed scale gauge* is the difference between the maximum and minimum scale pressures. For example, the span of 200/500 psi gauge is 300 psi.

The span of a *compound gauge* is the algebraic difference between the limits of the vacuum and pressure scales when both are expressed in the same units. For example: the span of 30 in. Hg vac (approximately –15 psi) to 30 psi pressure scale is 45 psi.

span adjustment — see *adjustment, span*

span, compound gauge — see *span*

span, suppressed scale — see *span*

specific service gauge — see *gauge, specific service*

spike — a short duration, high amplitude sudden rise or drop in system pressure

spontaneous explosive failure — see *failure, explosive*

standard — see *standard, calibration*

standard, calibration — a pressure instrument used to determine the accuracy of a gauge (see ASME/ANSI PTC 19.2)

standard, transfer — see ASME/ANSI PTC 19.2

standard, working — see ASME/ANSI PTC 19.2

steady pressure — see *pressure, steady*

stem (socket) — the main supporting component of the pressure element assembly to which the elastic element is attached. It may include the pressure connection and mounting for the movement and case.

stop — the component that limits the motion of the pointer (see *stop, internal*, and *stop pin*)

stop, internal — a stop designed to restrain the pressure element motion by acting directly on it or on the movement mechanism (see para. 3.3.6)

stop pin — the component on the dial that limits the angular rotation of the pointer

suppressed scale gauge — see *gauge, suppressed scale*

surface (wall) mounted — see *gauge, surface (wall) mounted*

surface, wetted — any surface that directly contacts the pressure media

takeup — the portion of the scale between the position where the pointer is stopped and its true zero pressure position

temperature, ambient — the temperature of the atmosphere surrounding the gauge

temperature coefficient — see *coefficient, temperature*

temperature error — see *error, temperature*

temperature, process — the temperature of the process medium at the pressure connection of the socket

temperature, storage — the extremes of temperature (high and low) that the gauge may be exposed to when it is not pressurized

test gauge — see *gauge, test*

threaded ring — see *ring, threaded*

threaded window — see *window, threaded*

tip — the motion or force transmitting component at the free end of an elastic element

torr — see para. 3.3.2.1

traceability — documentation of the existence of a calibration chain between an instrument and a primary standard

transfer standard — see *standard, transfer*

vacuum gauge — see *gauge, vacuum*

vacuum — see *pressure, negative*

variable pressure — see *pressure, variable*

vibration resistance — the maximum sinusoidal acceleration a gauge can withstand without damage or evidence of a change in accuracy of more than a specified value. It is expressed in g's, or amplitude over a frequency range and time period.

welding — a metal joining process wherein coalescence is produced by heating to suitable temperatures to melt together the base metals with or without the addition of filler metal. If filler metal is used, it shall have a melting point and composition approximately the same as the base metal.

window — a transparent component that closes the front of the case (see Fig. 2)

window, heat treated glass — a window of specially heat treated (tempered) glass, which, when broken, will form into small, granular pieces usually with no jagged edges

window, laminated glass — a window with two or more sheets of glass held together by an intervening layer(s) of clear plastic. When it is cracked or broken, the pieces of glass tend to adhere to the plastic.

window, plain glass — a window of commercial single or double strength plate or sheet glass

window, plastic — a window of transparent plastic

window, threaded — window, generally made of plastic, with integral threads that match threads on the case. No separate ring is required.

3 GENERAL RECOMMENDATIONS

3.1 Gauge Sizes

Size	Approximate Inside Diam. of Case at Face of Dial (mm)
1½	40
2	50
2½	65
3½	90
4½	115
6	150
8½	215
12	305
16	405

3.2 Preferred Ranges

3.2.1 Positive Pressure

in. H_2O	psi		
0/10	0/3	0/200	0/6.000
0/15	0/5	0/300	0/10.000
0/30	0/10	0/600	0/15.000
0/60	0/15	0/1.000	0/30.000
0/100	0/30	0/1.500	0/60.000
0/200	0/60	0/3.000	0/100.000
0/300	0/100		

kPa					
0/1	0/10	0/100	0/1 000	0/10 000	0/100 000
0/1.6	0/16	0/160	0/1 600	0/16 000	0/160 000
0/2.5	0/25	0/250	0/2 500	0/25 000	0/250 000
0/4	0/40	0/400	0/4 000	0/40 000	0/400 000
0/6	0/60	0/600	0/6 000	0/60 000	0/600 000

bar					
0/0.01	0/0.10	0/1.0	0/10	0/100	0/1000
0/0.016	0/0.16	0/1.6	0/16	0/160	0/1600
0/0.025	0/0.25	0/2.5	0/25	0/250	0/2500
0/0.04	0/0.40	0/4.0	0/40	0/400	0/4000
0/0.06	0/0.60	0/6.0	0/60	0/600	0/6000

3.2.2 Negative Pressure (Vacuum)

in. Hg	kPa	bar
−30/0	−100/0	−1/0

3.2.3 Compound Pressure

in. Hg/psi	kPa	bar
30 in. Hg vac/15 psi	−100/150	−1/1.5
30 in. Hg vac/30 psi	−100/300	−1/3
30 in. Hg vac/60 psi	−100/500	−1/5
30 in. Hg vac/100 psi	−100/900	−1/9
30 in. Hg vac/150 psi	−100/1500	−1/15
	−100/2400	−1/24

3.2.4 Receiver

psi	kPa	bar
3/15	20/100	0.2/1.0

NOTE: Other ranges are in common use and accepted, but less preferred by this Standard.

3.3 Construction

3.3.1 Cases. See Fig. 4.

3.3.1.1 General. Cases may be fabricated from various materials using various manufacturing processes. They may have solid fronts or open fronts, and may or may not employ various case pressure relief means. Specific applications may require design variations with respect to case construction. There should be mutual agreement between user, supplier, or manufacturer, or some combination, regarding the applications and the design variations.

3.3.1.2 Cases With Pressure Relief Means. For gauges used to measure gas pressures of 400 psi (2800 kPa) and higher and liquid pressures of 1000 psi (7000 kPa) and higher, cases with pressure relief means are recommended.

3.3.1.3 Solid Front With Pressure Relief Back. In the event of failure of the elastic element within its rated pressure range, the solid front (partition between the pressure element and the window) and the pressure relief back shall be designed to reduce the possibility of window failure and projection of parts outward through the front of the gauge. The user should consult with the manufacturer regarding the degree of protection required (see section 4).

Normal mounting of the gauge shall not prevent proper functioning of the pressure relief means.

3.3.1.4 Open Front With Pressure Relief. In the event of a slow leak of media through the elastic element, the case pressure relief shall be sufficient to vent the case pressure increase before window failure occurs. If case pressure increases rapidly, however, the case pressure relief device may not prevent parts from being expelled.

Normal mounting of the gauge shall not prevent proper function of the case pressure relief means.

3.3.1.5 Mounting. Mounting holes or studs are used for flush and surface mounted gauges. They shall be sized and located as shown in Fig. 6.

3.3.2 Dials

3.3.2.1 Common Units

(a) Over the years, different classifications of units of measure have been used. Many of the older units, although not presently officially recognized by standard setting bodies, are still in widespread use and are therefore included in this Standard for the purpose of definition. The three basic classifications are as follows.

(1) SI (Le Système International d'Unités) — these units are recognized by the CIPM (Comité International des Poids et Measures);

(2) MKSA (meter, kilogram-force, second, ampere) — the former metric units, which are being replaced by the SI units.

(3) Customary (inch, pound-force, second, ampere) — customary units are used primarily in English-speaking countries and are being replaced in most countries by SI units.

(b) Definitions of the various units are as follows.

SI Abbreviation	Unit	Definition
bar	bar	1 bar = 100 kPa (The bar is a unit outside the SI, which is nevertheless recognized by CIPM.)
kPa	kilopascal	1 kPa = 1000 Pa
mbar	millibar	1 mbar = bar/1000 = 100 Pa
MPa	megapascal	1 MPa = 1 000 000 Pa
N/m^2	newton per square meter	1 N/m^2 = 1 Pa
Pa	pascal	1 Pa = 1 N/m^2

MKSA Abbreviation	Unit	Definition
kg/cm^2	kilograms per square centimeter	1 kg/cm^2 = 1 kilogram force per square centimeter
m H_2O	meters of water	1 m H_2O = 1 meter of water at 68°F (20°C)
mm Hg	millimeters of mercury	1 mm Hg = 1 millimeter of mercury at 32°F (0°C)
torr	torr	1 torr = 1.0 mm Hg absolute pressure

Customary Abbreviation	Unit	Definition
ft. sea water	ft. sea water	1 ft sea water = 0.4453 psi
in. Hg	inches of mercury	1 in. Hg = 1 in. of mercury at 32°F (0°C) (0.4911 psi)
in. H_2O (20°C)	inches of water (Ref. ISA RP2.1)	1 in. H_2O (20°C) = 1 in. of water at 20°C (68°F), and 980.665 cm/sec gravity (0.036063 psi)
in. H_2O (60°F)	inches of water (Ref. AGA Report #3)	1 in. H_2O (60°F) = 1 in. of water at 60°F (15.6°C), and 980.665 cm/sec. gravity (0.036092 psi)
oz/in.^{2}	ounces per square inch	1 oz/in.^{2} = 1 ounce force per square inch
psi	pounds per square inch	1 psi = 1 pound force per square inch gauge pressure
psia	pounds per square inch absolute	1 psia = 1 pound force per square inch absolute pressure
psid	pounds per square inch differential	1 psid = 1 pound force per square inch differential pressure

3.3.2.2 Units. Dials shall indicate the units in which the scale is graduated.

On dials with multiple scales, each scale shall indicate the units in which it is graduated.

Dual pressure scale dials are useful where gauges are employed on equipment that may be used internationally, or where users plan to convert from one unit of measure to another over a period of time. One of the scales shall be one of the preferred ranges (see para. 3.2).

Receiver gauge dials shall indicate the input pressure range of the gauge.

Dials with a scale graduated in nonpressure units, or a scale range different from the range of the pressure element assembly, shall clearly indicate the maximum pressure that may be applied to the gauge without loss of calibration.

The use of multipliers, such as ×100, ×1000, and ×100 kPa, is discouraged because of potential misapplication or misinterpretation.

All of the above units mean gauge pressure unless otherwise specified, except when psia, psid, or torr are displayed. For all other units, absolute or differential pressures are indicated by adding the words ABSOLUTE or DIFFERENTIAL. Upper- or lowercase letters are acceptable. When space does not permit, the abbreviation ABS of DIFF may be used.

Negative (vacuum) values shall be indicated by preceding the appropriate numerals with a minus (–) or clearly marking the dial with the words VAC or VACUUM. Upper- or lowercase letters are acceptable. Both signs and words should not appear on the same scale.

The absence of a sign before a numeral indicates a positive value except when accompanied by the words VAC or VACUUM.

The pointer shall rotate clockwise for increasing positive pressure and counterclockwise for increasing negative pressure.

3.3.2.3 Scale Graduations. The recommended graduated scale is 270 deg. Special applications and ranges may require scale arcs greater or less than 270 deg.

3.3.2.4 Graduation Lines. Graduation lines shall be radial to the center of rotation of the pointer and shall project beyond the arc described by the end of the pointer (mirror and multiple scale dials excepted). Major and intermediate graduation lines shall be emphasized. Graduations shall not extend beyond the calibrated portion of the scale.

Scale numeral and graduation increments should follow the format: 1×10^n, 2×10^n, or 5×10^n, where n is a whole ± number or zero.

The smallest graduation increment should not exceed twice the error permitted (accuracy) in the middle half of the scale.

3.3.2.5 Graduation Near Zero. On dials for Grades 4A and 3A gauges, there shall be no takeup. The number and the spacing of the minor graduations near zero,shall be the same, commencing at the true zero, as in the rest of the scale. On dials for all other grades, take up may be incorporated. However, if it is incorporated, it shall be readily apparent at what pressure the graduations start. A zero graduation or numeral, or both, shall not be permitted at the stopped pointer position on gauges using a stop pin or internal stops that prevent free pointer motion to the actual zero pressure position.

3.3.2.6 Markings. Dial markings may include manufacturer's or customer's trademark, or both, and any other information deemed appropriate for safety of specific service requirements (see para,. 4.3.8)

3.3.2.7 Numerals. Numerals shall be sufficient in number to enable the operator to accurately and quickly identify any pressure on the scale. They shall not obscure or crowd graduations or important markings.

Numerals shall not extend beyond the calibrated portion of the scale.

3.3.3 Pointers

3.3.3.1 Length (All Grades). The tip of the pointer shall pass within one minor graduation line width of the inner end of the minor graduations.

The pointer may overlap the graduations.

3.3.3.2 Tip Width (Grades 4A and 3A). The width of the pointer tip shall not be greater than the width of the minor graduation lines.

3.3.4 Pressure Connection

3.3.4.1 Location of Connection

(a) Stem mounted – bottom or back
(b) Surface mounted – bottom or back
(c) Flush mounted – back

3.3.4.2 Type of Connection. Taper pipe connections for pressures up through 20,000 psi or 160,000 kPa are usually $\frac{1}{8}$-27 NPT, $\frac{1}{4}$-18 NPT, or $\frac{1}{2}$-14 NPT American Standard external or internal taper pipe threads per ANSI/ASME B1.20.1 as required. Above this pressure, $\frac{1}{4}$ high pressure tubing connections, or equal, may be used. Other appropriately sized connections, employing sealing means other than tapered threads, are acceptable.

In applications of stem mounted gauges, especially with liquid filled cases and where vibration is severe, consideration should be given to the possibility of failure of the stem or associated piping caused by the vibrating mass of the gauge. A larger connection (e.g., $\frac{1}{2}$ NPT instead of $\frac{1}{4}$ NPT) or a stronger stem material (e.g., stainless steel instead of brass), or both, should be considered.

3.3.5 Rings. Removable rings, size $4\frac{1}{2}$ and larger, generally have window retaining devices.

3.3.6 Internal Stop. An internal stop is a device that restrains the motion of the pressure element or the mechanism to reduce the probability of damage to the pressure element or disengagement of the movement mechanism caused by application of pres-

sure below the minimum scale value or above the maximum scale value. It will also reduce the possibility of disengagement of the movement mechanism caused by the inertial effect of sudden pressure changes.

3.3.6.1 Maximum Stop. Maximum stop shall prevent pointer motion beyond a point approximately midway between the last and the first dial graduation and shall prevent the pointer from striking an obstruction. Pointer motion shall be be restrained at less than 105% of full scale pressure.

3.3.6.2 Minimum Stop. Minimum stop shall prevent pointer motion below a point 5% lower than the first scale graduation and a point approximately midway between the last and the first dial graduation. When incorporated, requirements of para. 3.3.2.4 shall apply.

3.3.7 Windows

3.3.7.1 Laminated Glass. Laminated glass shall comply with ANSI Z26.1. Laminated glass offers some protection in all applications. It reduces the possibility of glass particles scattering if the pressure element ruptures and window failure results.

3.3.7.2 Heat Treated Glass. Heat treated glass shall comply with ANSI Z26.1. Heat treated glass has greater resistance to mechanical damage than plain glass.

3.3.7.3 Plastic. Impact and abrasive environmental conditions, especially temperature and corrosive atmosphere, must be carefully considered to determine the type of plastic best suited for the application.

3.3.7.4 Plain Glass. This window material is commonly used due to its abrasion, chemical, and wear resistance properties. Careful consideration of its use should be given for hazardous applications.

3.4 Accuracy

Presure gauge accuracy is graded as shown in Table 1 (see section 6 for testing procedures).

3.4.1 General Discussion

3.4.1.1 Elastic elements are made of many materials to meet various requirements of corrosion resistance and performance. A corrosive pressure medium may dictate use of an element material having less than optimum spring properties. The accuracy classification of such a gauge depends to a large extent on these spring properties.

3.4.1.2 Using a pressure gauge in an environment or with media that cause the temperature of the elastic element to be different from that at which it was calibrated will increase the indication error. This is caused by temperature effects on the elastic element and the mechanism connecting it to the pointer.

3.4.1.3 Temperature change affects the stiffness of the elastic element. The change in stiffness of a material with change in temperature is the thermoelastic coefficient (TEC) of the material. Stiffness change is produced by a combination of changes in the elastic modulus (Young's Modulus) due to thermal effects and a change in linear dimensions due to linear expansion and contraction. Except when special element materials are employed, such as NI-SPAN-C[1] Alloy 902 (an alloy that can be heat treated to control TEC), the error caused by temperature change will be approximately 1% at full scale pressure for each 50°F (28°C) change in temperature. This error is approximately proportional to the applied pressure and therefore cannot be corrected by resetting the pointer.

For a given temperature condition, correction can be made by calculating the approximate error at each applied pressure value and adding it to or subtracting it from the indicated value. If the temperature condition is stable and a more accurate indication is required, recalibration may be appropriate.

3.4.1.4 Gauges represented as being compensated for service at various temperatures generally have components of special materials and design to compensate not only for the temperature effects on the elastic element stiffness, but also to compensate for similar effects on the gauge mechanism. The accuracy classification of a temperature compensated gauge is established by the magnitude of the largest error encountered when the gauge is tested over its entire rated service temperature range.

3.4.1.5 Sealed cases, liquid filled or not, will exhibit additional error as a result of exposure to ambient or media temperature different from that at which the case was sealed unless compensation is provided. This error is caused by internal case pressure changes and depends on fill media, extent of fill, and other factors.

[1]NI-SPAN-C is a registered trademark of the International Nickel Company, Inc.

TABLE 1 ACCURACY GRADES

Accuracy Grade	Permissible Error (+/− Percent of Span) (Excluding Friction) Lower 1/4 of Scale	Middle 1/2 of Scale	Upper 1/4 of Scale	Maximum Friction (Percent of Span)	Minimum Recommended Gauge Size (270 deg. Dial Arc)
4A	←	0.1	→	[Note (1)]	8½
3A	←	0.25	→	0.25	4½
2A	←	0.5	→	0.5	2½
1A	←	1.0	→	1.0	1½
A	2.0	1.0	2.0	1.0	1½
B	3.0	2.0	3.0	2.0	1½
C	4.0	3.0	4.0	3.0	1½
D	5.0	5.0	5.0	3.0	1½

NOTE:
(1) Grade 4A gauges must remain within specified tolerance before and after being lightly tapped.

The error is constant over the entire scale, and if the temperature is stable, within limits, it can be corrected by resetting the pointer.

An increase in temperature generally causes an increase in internal case pressure with a resulting decrease in indicated pressure. The opposite occurs for a decrease in temperature.

For a given temperature change, the percentage of error noted on the gauge is a function of the range (or span) of the gauge. If, for example, the temperature increases causing the internal case pressure to increase by 3 psi, then on a 0/30 psi gauge, this will cause a −10% error, whereas on a 0/100 psi gauge, the error will be −3%. For higher ranges, the percentage of error becomes proportionately less.

3.4.1.6 The accuracy of a retard gauge shall be expressed as a percentage of the expanded portion of the scale. The accuracy classification of the gauge is not determined by its accuracy in the compressed portion of the scale. The accuracy for the compressed portion of the scale may be substantially different. Consult the manufacturer or supplier for specific information.

3.4.1.7 The accuracy of a gauge with suppressed scale shall be expressed as a percentage of span.

3.4.1.8 The accuracy of a compound gauge shall be expressed as a percentage of span.

3.4.1.9 Accuracy is affected by readability. For this reason, more accurate gauges are generally made in larger sizes (see Table 1).

3.4.1.10 Mounting a pressure gauge in a position other than that at which it was calibrated can affect its accuracy. Normal calibrating position is upright and vertical. For applications requiring mounting in other than this position, notify the supplier.

3.4.1.11 Some absolute pressure gauges are pressure gauges with the pointer set to indicate 14.7 psia with the elastic element unpressurized. These gauges indicate in terms of absolute pressure, but will be in error by the difference between the ambient pressure and 14.7 psia. Other absolute pressure gauges indicate the correct absolute pressure value, even though the ambient pressure may vary.

3.4.1.12 Pressure gauges can be rendered inaccurate during shipment despite care taken in packaging. To ensure conformance to the standard grade to which the pressure gauge was manufactured, it should be checked before use.

3.5 Installation

Before installing a pressure gauge, consideration should be given to temperature, humidity, vibration, pulsation, shock, and other climatic and ambient conditions of the service application, and the possible need for protective attachments and/or special installation requirements.

Refer to Safety (see section 4).

The gauge connection must be compatible with the mating connection, and appropriate assembly techniques must be utilized.

Installation of the gauge should be accomplished by tightening the pressure connection using the wrench flats if provided. Failure to do so may result in loss of accuracy, excessive friction or mechanical damage to the pressure element or case.

4 SAFETY

4.1 Scope

This section of the Standard presents certain information to guide users, suppliers, and manufacturers toward minimizing the hazards that could result from misuse or misapplication of pressure gauges with elastic elements. The user should become familiar with all sections of this Standard, as all aspects of safety cannot be covered in this section. Consult the manufacturer or supplier for advice whenever there is uncertainty about the safe application of a pressure gauge.

4.2 General Discussion

4.2.1 Adequate safety results from intelligent planning and careful selection and installation of gauges into a pressure system. The user should inform the supplier of all conditions pertinent to the application and environment so that the supplier can recommend the most suitable gauge for the application.

4.2.2 The history of safety with respect to the use of pressure gauges has been excellent. Injury to personnel and damages to property have been minimal. In most instances, the cause of failure has been misuse or misapplication.

4.2.3 The pressure sensing element in most gauges is subjected to high internal stresses, and applications exist where the possibility of catastrophic failure is present. Pressure regulators, chemical (diaphragm) seals, pulsation dampers or snubbers, syphons, and other similar items, are available for use in these potentially hazardous systems. The hazard potential increases at higher operating pressure.

4.2.4 The following systems are considered potentially hazardous and must be carefully evaluated:

(a) compressed gas systems;
(b) oxygen systems;
(c) systems containing hydrogen or free hydrogen atoms;
(d) corrosive fluid systems (gas and liquid);
(e) pressure systems containing any explosive or flammable mixture or medium;
(f) steam systems;
(g) nonsteady pressure systems;
(h) systems where high overpressure could be accidentally applied;
(i) systems wherein interchangeability of gauges could result in hazardous internal contamination or where lower pressure gauges could be installed in higher pressure systems;
(j) systems containing radioactive or toxic fluids (liquids or gases);
(k) systems installed in a hazardous environment.

4.2.5 When gauges are to be used in contact with media having known or uncertain corrosive effects or known to be radioactive, random or unique destructive phenomena can occur. In such cases the user should always furnish the supplier or manufacturer with information relative to the application and solicit his advice prior to installation of the gauge.

4.2.6 Fire and explosions within a pressure system can cause pressure element failure with very violent effects, even to the point of completely disintegrating or melting the pressure gauge. Violent effects are also produced when failure occurs due to:

(a) hydrogen embrittlement;
(b) contamination of a compressed gas;
(c) formation of acetylenes;
(d) weakening of soft solder joints by steam or other heat sources;
(e) weakening of soft soldered or silver brazed joints caused by heat sources such as fires;
(f) corrosion;
(g) fatigue;
(h) mechanical shock;
(i) excessive vibration.

Failure in a compressed gas system can be expected to produce violent effects.

4.2.7 Modes of Pressure Gauge Failure

4.2.7.1 Fatigue Failure. Fatigue failure caused by pressure induced stress generally occurs from the inside to the outside along a highly stressed edge radius, appearing as a small crack that propagates along the edge radius. Such failures are usually more critical with compressed gas media than with liquid media.

Fatigue cracks usually release the media fluid slowly so case pressure buildup can be averted by providing pressure relief openings in the gauge case. However, in high pressure elastic elements where the yield strength approaches the ultimate strength of the element material, fatigue failure may resemble explosive failure.

A restrictor placed in the gauge pressure inlet will reduce pressure surges and restrict fluid flow into the partially open Bourdon tube.

4.2.7.2 Overpressure Failure. Overpressure failure is caused by the application of internal pressure greater than the rated limits of the elastic ele-

ment and can occur when a low pressure gauge is installed in a high pressure port or system. The effects of overpressure failure, usually more critical in compressed gas systems than in liquid filled systems, are unpredictable and may cause parts to be propelled in any direction. Cases with pressure relief openings will not always retain expelled parts.

Placing a restrictor in the pressure gauge inlet will not reduce the immediate effect of failure, but will help control flow of escaping fluid following rupture and reduce the potential of secondary effects.

It is generally accepted that solid front cases with pressure relief back will reduce the possibility of parts being projected forward in the event of failure.

The window alone will not provide adequate protection against internal case pressure buildup, and can be the most hazardous component.

Short duration pressure impulses (pressure spikes) may occur in hydraulic or pneumatic systems, especially when valves open or close. The magnitude of the spikes may be many times the normal operating pressure, and may not be indicated by the gauge. The result could be immediate failure, or a large upscale error. A restrictor (snubber) may reduce the magnitude of the pressure transmitted to the elastic element.

4.2.7.3 Corrosion Failure. Corrosion failure occurs when the elastic element has been weakened through attack by corrosive chemicals present in either the media inside or the environment outside it. Failure may occur as pinhole leakage through the element walls or early fatigue failure due to stress cracking brought about by chemical deterioration or embrittlement of the material.

A chemical (diaphragm) seal should be considered for use with pressure media that may have a corrosive effect on the elastic element.

4.2.7.4 Explosive Failure. Explosive failure is caused by the release of explosive energy generated by a chemical reaction such as can result when adiabatic compression of oxygen occurs in the presence of hydrocarbons. It is generally accepted that there is no known means of predicting the magnitude or effects of this type of failure. For this mode of failure, a solid wall or portion between the elastic element and the window will not necessarily prevent parts being projected forward.

4.2.7.5 Vibration Failure. The most common mode of vibration failure is that where the movement parts wear because of high cyclic loading caused by vibration, resulting in gradual loss of accuracy, and, ultimately failure of the pointer to indicate any pressure change.

4.2.7.6 Vibration-Induced Fatigue Failure. In addition to its effect on the gauge movement and linkage (see para. 4.2.7.5) vibration may, in some instances, result in high loading of various parts of the pressure element assembly. This loading could cause cracks in the element itself, or in joints. Case pressure buildup may be slow, but it is possible that a large hole may suddenly develop, with a high rate of case pressure rise, which could result in a failure similar to an explosive failure.

4.2.8 Pressure Connection. See recommendations in para. 3.3.4.

4.3 Safety Recommendations

4.3.1 Operating Pressure. The pressure gauge selected should have a full scale pressure such that the operating pressure occurs in the middle half (25% to 75%) of the scale. The full scale pressure of the gauge selected should be approximately two times the intended operating pressure.

Should it be necessary for the operating pressure to exceed 75% of full scale, contact the supplier for recommendations.

This does not apply to test, retarded, or suppressed scale gauges.

4.3.2 Use of Gauges Near Zero Pressure. The use of gauges near zero pressure is not recommended because the accuracy tolerance may be a large percentage of the applied pressure. If, for example, a 0/100 psi Grade B gauge is used to measure 6 psi, the accuracy of measurement will be +3 psi, or ±50% of the applied pressure. In addition, the scale of a gauge is often laid out with takeup, which can result in further inaccuracies when measuring pressures that are a small percentage of the gauge span.

For the same reasons, gauges should not be used for the purpose of indicating that the pressure in a tank, autoclave, or other similar unit has been completely exhausted to atmospheric pressure. Depending on the accuracy and the span of the gauge and the possibility that takeup is incorporated at the beginning of the scale, hazardous pressure may remain in the tank even though the gauge is indicating zero pressure. A venting device must be used to completely reduce the pressure before unlocking covers, removing fittings, or performing other similar activities.

4.3.3 Compatibility With the Pressure Medium. The elastic element is generally a thin walled member, which of necessity operates under high stress conditions and must, therefore, be carefully selected for compatibility with the pressure medium being measured. None of the common element materials is impervious to every type of chemical attack. The potential for corrosive attack is established by many factors, including the concentration, temperature, and contamination of the medium. The user should inform the gauge supplier of the installation conditions so that the appropriate element materials can be selected.

4.3.4 In addition to the factors discussed above, the capability of a pressure element is influenced by the design, materials, and fabrication of the joints between its parts.

Common methods of joining are soft soldering, silver brazing, and welding. Joints can be affected by temperature, stress, and corrosive media. Where application questions arise, these factors should be considered and discussed by the user and manufacturer.

4.3.5 Some special applications require that the pressure element assembly have a high degree of leakage integrity. Special arrangement should be made between manufacturer and user to assure that the allowable leakage rate is not exceeded.

4.3.6 Cases

4.3.6.1 Cases, Solid Front. It is generally accepted that a solid front case per para. 3.3.1 will reduce the possibility of parts being projected forward in the event of elastic element assembly failure. An exception is explosive failure of the elastic element assembly.

4.3.6.2 Cases, Liquid Filled. It has been general practice to use glycerine or silicone filling liquids. However, these fluids may not be suitable for all applications. The should be avoided where strong oxidizing agents including, but not limited to, oxygen, chlorine, nitric acid, and hydrogen peroxide are involved. In the presence of oxidizing agents, potential hazard can result from chemical reaction, ignition, or explosion. Completely fluorinated or chlorinated fluids, or both, may be more suitable for such applications.

The user shall furnish detailed information relative to the application of gauges having liquid filled cases and solicit the advice of the gauge supplier prior to installation.

Consideration should also be given to the instantaneous hydraulic effect that may be created by one of the modes of failure outlined in para. 4.2.7. The hydraulic effect due to pressure element failure could cause the window to be projected forward even when a case having a solid front is employed.

4.3.7 Restrictor. Placing a restrictor between the pressure connection and the elastic element will not reduce the immediate effect of failure, but will help control flow of escaping fluid following rupture and reduce the potential of secondary effects.

4.3.8 Specific Service Conditions

4.3.8.1 Specific applications for pressure gauges exist where hazards are known. In many instances, requirements for design, construction, and use of gauges for these applications are specified by state or federal agencies or Underwriters Laboratories, Inc. Some of these specific service gauges are listed below. The list is not intended to include all types, and the user should always advise the supplier of all application details.

4.3.8.2 Acetylene Gauge. A gauge designed to indicate acetylene pressure. It shall be constructed using materials that are compatible with commercially available acetylene. The gauge may bear the inscription ACETYLENE on the dial.

4.3.8.3 Ammonia Gauge. A gauge designed to indicate ammonia pressure and to withstand the corrosive effects of ammonia. The gauge may bear the inscription AMMONIA on the dial. It may also include the equivalent saturation temperature scale markings on the dial.

4.3.8.4 Chemical Gauge. A gauge designed to indicate the pressure of corrosive or high viscosity fluids, or both. The primary material(s) in contact with the pressure medium may be identified on the dial. It may be equipped with a chemical (diaphragm) seal, pulsation damper, or pressure relief device, or a combination. These devices help to minimize potential damage to personnel and property in the event of gauge failure. They may, however, also reduce accuracy or sensitivity, or both.

4.3.8.5 Oxygen Gauge. A gauge designed to indicate oxygen pressure. Cleanliness shall comply with Level IV (see section 5). The dial shall be clearly marked with a universal symbol and/or USE NO OIL in red color (see para. 6.1.2.1).

4.4 Reuse of Pressure Gauges

It is not recommended that pressure gauges be moved from one application to another. Should it be

necessary, however, the following must be considered.

4.4.1 Chemical Compatibility. The consequences of incompatibility can range from contamination to explosive failure. For example, moving an oil service gauge to oxygen services can result in explosive failure.

4.4.2 Partial Fatigue. The first installation may involve pressure pulsation that has expended most of the gauge life, resulting in early fatigue in the second installation.

4.4.3 Corrosion. Corrosion of the pressure element assembly in the first installation may be sufficient to cause early failure in the second installation.

4.4.4 Other Considerations. When reusing a gauge, all guidelines covered in this Standard relative to application of gauges should be followed in the same manner as when a new gauge is selected.

5 CLEANLINESS

5.1 General

This section provides standardized reference for gauge users in specifying cleanliness requirements and guidance to manufacturers in meeting these requirements.

If gauge cleanliness is important for the application, such as for use on equipment involving food processing, life support, or oxidizing fluids, the user should specify the appropriate level of cleanliness listed in Table 2.

If the cleanliness requirements of the intended application are not covered in this Table, the user should so advise the manufacturer.

5.2 Cleanliness Levels

Cleanliness is determined by the size and quantity of maximum permmissible solid contaminants on wetted surfaces or by the quantity of contaminant (hydrocarbons) discernible in the fluids used to flush or clean such surfaces, or by both. Common cleanliness levels are defined in Table 2.

5.3 Inspection for Cleanliness

Hydrocarbon concentration may be determined by methods such as infrared spectrophotometry or black light (ultraviolet) radiation of the long wave type [approximately 3600 angstrom units (360 nm)], where the solvent used to flush the pressure element assembly is evaluated.

When black light radiation methods are employed, the manufacturer should ascertain that the solvent used will dissolve all hydrocarbons that could be present and that all hydrocarbons are detectably fluorescent under black light. It may be necessary for the gauge manufacturer to add fluorescent additives to certain suspected contaminants to make their detection possible.

The dimensions of particles and fibers are usually determined by microscopic examination of filter paper through which the flushing solvent has been passed.

5.4 Packaging

Gauges shall be packaged in such a manner that specified cleanliness requirements are maintained.

The user shall take proper precautions so that cleanliness levels for socket and pressure element are maintained after the gauge is removed from its package for installation.

6 PRESSURE GAUGE TESTING

6.1 Calibration Standards

6.1.1 General Discussion

6.1.1.1 Complete information regarding manometers and piston gages is contained in ASME/ANSI PTC 19.2. In computing the accuracy of these instruments, their geographical location must be accurately ascertained and corrections applied as outlined in NIST Manometry Manual and NIST Piston Gage Manual.

6.1.1.2 Working standards (gauges or transducers) used as calibration standards shall have an accuracy that is significantly better than that of the gauges to be tested and that has a documented path to NIST (see para. 6.1.2.1). Refer to NIST Technical Note on Error Assessment).

6.1.1.3 Working standards shall be tested before and after a period of use. The frequency of recalibration will depend on their ability to retain their accuracy during use. The indicating error for each cardinal point and the date of last calibration shall be noted prominently on the front of the instrument.

6.1.1.4 Indicating dial gauges used as working standards may be equipped with a device or devices to minimize parallax reading errors. The test gauge

TABLE 2 CLEANLINESS LEVELS

Cleanliness Level [Note (1)]	General Cleanliness Requirements Applicable to All Levels	Allowable Size and Quantity: Particles Size (Micrometers)	Particles Maximum Quantity [Note (2)]	Fibers Size (Micrometers)	Fibers Maximum Quantity [Note (2)]	Hydrocarbon ppm [Note (3)], Maximum
I	Normal cleanliness attained through high standard shop practices	No limit	No limit	No limit	No limit	No limit
IV	Gauge shall be free of visually [Note (4)] (unaided eye) detectable moisture and foreign matter (chips, slivers, weld slag or splatter, shop soil, greases, oils, or other contaminants) that could be mechanically detrimental to proper function of gauge	Less than 100 100/500 Over 500	No limit 25 0	Less than 700 700/1000 Over 1000	No limit 10 0	50

NOTES:
(1) Levels II and III intentionally omitted.
(2) Quantity = number by count per solvent flush.
(3) Ppm per solvent flush (approximately the volume contained by the wetted surface).
(4) Excluding particle, fiber, and hydrocarbon detection procedures.

should not have a stop pin unless it is located below the true zero pressure point of the graduated scale. See para. 6.1.2.1 and Table 1 for recommended accuracy and sizes.

6.1.1.5 Liquid pressure media should not be used to calibrate gauges where the weight of the liquid in the pressure element will induce errors. This effect is greater on low pressure range gauges.

6.1.2 Recommended Standards

6.1.2.1 Use of the instruments suggested below is not mandatory, but the standards of weight, density, and linear measurements used in manufacturing and calibrating the test instrument shall conform to equivalent measuring standards that have been calibrated at the National Institute of Standards and Technology and shall be documented. The working standard, at the pressure being tested, shall be at least four times as accurate as the gauge being tested. If the accuracy level is less than four times, allowance for error in the standard is necessary. If a liquid pressure medium is used, correction for liquid head effect is necessary. CAUTION: Piston gages containing oil or other hydrocarbon fluids shall not be used to calibrate oxygen gauges or gauges cleaned to Level IV. See Table 2.

6.1.2.2 Accuracy Grades 4A and 3A. Manometers or piston gages (as appropriate).

6.1.2.3 Accuracy Grades 2A, 1A, A, B, C, and D

(a) 30 in. Hg vac through 100 psi or –100 kPa through 1000 kPa – manometer or piston gage, specially calibrated test gauge, or transducer.

(b) Above 100 psi or 1000 kPa – piston gage, test gauge specially calibrated, or transducer.

6.2 Verification Test Procedures

The following procedures are suggested when testing a pressure gauge to determine its compliance with the accuracy grades defined in para. 3.4. Statistical methods or alternate test procedures, or both, may be used when agreed to by the manufacturer and the user.

6.2.1 Reference Temperature (All Grades). A temperature of 73.4°F (23°C) shall be the reference standard for testing all gauges. Temperature compensated gauges shall be tested at several ambient temperatures within the range specified by the manufacturer.

6.2.2 Liquid Head. When used in connection with an air piston gauge, there shall be no liquid in the gauge or in the lines between the gauge and the piston gauge.

6.2.3 Procedures

6.2.3.1 Accuracy

(a) Grades 3A and 4A Only. Before conducting the accuracy test, subject the gauge to a pressure equal to the maximum scale pressure (or vacuum). Conduct the accuracy test within 10 min.

(b) All Grades. Known pressure shall be applied at each test point on increasing pressure (or vacuum) from one end to the other end of the scale. At each test point the gauge shall be read, lightly tapped, and then read again. The same sequence shall be repeated on decreasing pressure (or vacuum). The entire set of upscale and downscale readings shall then be repeated.

Accuracy Grade	Minimum Recommended Number of test Points [Note]
4A	10
3A, 2A, 1A, A	5
B, C, D	3

NOTE: The test points shall be distributed over the dial range and shall include points within 10% of the ends of the dial range.

The error can be determined from the data obtained in the two pressure cycles and is equal to the maximum error at each test point, in either direction, after tapping. For Grade 4A gauges only, the error must remain with tolerance both before and after tapping. When expressed as a percentage of span, the error shall not exceed the limits in Table 1 for the applicable grade of accuracy.

6.2.3.2 Repeatability. Repeatability can be determined from the data obtained in the two pressure cycles. It is the difference between any two readings taken after tapping, at the same pressure, approached from the same direction, and in the two pressure cycles, expressed in percentage of span. More than two pressure cycles may be desirable.

Repeatability does not include hysteresis or friction error.

6.2.3.3 Hysteresis. Hysteresis can be determined from the data obtained in the two pressure cycles. It is the difference at each test point between increasing pressure and decreasing pressure readings taken after tapping, at the same test point, approached from both increasing and decreasing pressure directions; in a single pressure cycle, expressed in percentage of span.

The hysteresis value is lower if the pressure excursion is less than full scale. Hysteresis is part of the accuracy.

6.2.3.4 Pointer Adjustment. Pointer adjustment can only be used to match the indication to a reference pressure at one point on the scale and should not be depended upon to recalibrate the gauge. Such an adjustment could cause a significant error at pressures above or below the setting point.

7 ORDERING PARAMETERS AND RELATED STANDARDS

7.1 Order Checklist

The following includes things to consider and questions to answer when ordering pressure gauges.

7.1.1 If user does not require assistance with selection and recommendation for service involved, specify:

(a) manufacturer's catalog number, size, range, and connection location and size; and

(b) variations or accessories, or both, if required.

7.1.2 If user requires moderate assistance, specify:

(a) range (specify units of measure) (see para. 3.2);

(b) accuracy (see para. 3.4);

(c) size (para. 3.1 and Fig. 6);

(d) material and method of joining of pressure containing components;

(e) connection type, location, and size;

(f) mounting (stem, surface, or flush) (see Fig. 6);

(g) approved manufacturer's catalog number; and

(h) variations or accessories, or both.

7.1.3 If user requires detailed assistance, specify items listed in para. 7.1.2 plus the applicable portions of the following:

(a) pressure fluid, name and state (gas or liquid), concentration, temperature, and material of equipment;

(b) pressure pulsation range and frequency;

(c) sudden pressure (less than 1/10 sec) increase or decrease;

(d) case and ring materials;

(e) window material;

(f) environmental conditions such as:

(1) vibration frequency and amplitude

(2) temperature

TABLE 3 SI (DIN) CASE SIZES

Gauge Size	Mounting Bolt Circle Diameter		Case Outside Diameter	
	mm	in	mm	in
50	60	2.36	50	1.97
63	75	2.95	63	2.48
80	95	3.74	80	3.15
100	116	4.57	100	3.94
160	178	7.01	160	6.30

(3) indoor and outdoor use
(4) corrosive atmosphere
(5) dust
(6) weather resistance
(7) humidity
(8) mechanical shock

(g) associated equipment.

7.2 Conversion Factors (Customary Units to SI Units)

The customary measuring units are listed below with their corresponding SI units and conversion factor will yield the correct value in SI units.

Customary Unit X	Conversion Factor [Note (1)]	= SI Unit
atmosphere (standard)	1.013 25 E + 05	Pa(pascal)
in.(inch)	2.540 00 E − 02	m(meter)
ft(foot)	3.048 00 E − 01	m
in. H_20(water) (20°C)	2.486 4 E +.2	Pa
in. H_20(water) (60°F)	2.488 5 E + 2	Pa
ft H_20 [Note (2)]	2.983 7 E + 03	Pa
in.^{2} (square inches)	6.451 60 E − 04	m^2 (square meters)
ft^2 (square feet)	9.290 30 E − 02	m^2
psi (pound force	6.894 76 E + 03	Pa
per square inch	6.894 76 E − 02	bar [Note (2)]
oz/in.^{2} (ounce per square inch)	4.309 22 E + 02	Pa
in.Hg (mercury) [Note 3]	3.386 38 E + 03	Pa
micron	1.000 00 E − 06	m
°F(degree Fahrenheit)	(°F − 32)/1.8	°C(degree Celsius)

NOTES:

(1) Conversion factors are expressed as a number between 1.0 and 10.0 with five decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits indicating the power of 10 by which the number must be multiplied to correctly place the decimal point. The plus or minus indicates the direction the decimal must be moved: plus to the right, minus to the left.
EXAMPLES:
(a) 2.540 00 E − 0.2 means 2.540 00 × 10^{-2} and equals 0.025 400
(b) 0.013 25 E + 05 means 1.013 25 × 10^5 and equals 101 325

(2) The bar is a unit outside the SI system that is nevertheless recognized by the Comitté International des Poids et Measures (CIPM).
1 bar × 1.000 000 E + 05 = Pa

(3) Mercury at 32°F (0°C).

7.3 SI (DIN) Case Sizes

This Standard defines gauge size as the approximate inside diameter of the case, in inches, at the dial. Other standards, such as the German DIN series, define gauge size as the precise outside diameter of the case. Because of this difference, a B40 gauge and DIN gauge may not be interchangeable, even though the nominal sizes are approximately 63.5 mm inside the case at the face of the dial. The outside diameter of the case may be as large as 70 mm, i.e., over 10% larger than a DIN 63 mm gauge.

The dimensions given in Table 3 are taken from the DIN standards.

APPENDIX A
SOME DEFINITIONS AND SUGGESTED TEST PROCEDURES USED TO MEASURE NEW GAUGE PERFORMANCE

(This Appendix is not an integral part of ASME B40.1-1991 and is included for information purposes only.)

A1 SCOPE

This Appendix is intended to provide an outline of the parameters used when evaluating new gauge performance and to suggest evaluation outlines. These test methods may or may not satisfy the requirements of the intended application. When it is known that the gauges will encounter conditions more severe or less severe than those specified, the test may be modified to match more closely the application. A functional test in the intended application is generally the best evaluation method.

A2 EVALUATION PROCEDURES

WARNING: FAILURES DURING PRESSURE TESTING ARE UNPREDICTABLE AND MAY CAUSE PARTS TO BE PROPELLED IN ANY DIRECTION. ALL PRESSURE TESTING SHOULD BE CONDUCTED BY QUALIFIED PERSONNEL USING APPROPRIATE SAFETY EQUIPMENT SUCH AS SAFETY GLASSES, SHIELDS, OR ENCLOSURES, OR A COMBINATION, TO PREVENT PERSONAL INJURY AND PROPERTY DAMAGE. READ SECTION 4 BEFORE CONDUCTING ANY TESTING.

A2.1 Accuracy

Per this Standard (see para. 6.2.3).

A2.2 Repeatability

Per this Standard (see para. 6.2.3.3).

A2.3 Hysteresis

Per this Standard (see para. 6.2.3.3).

A2.4 Pointer Adjustment

Per this Standard (see para. 6.2.3.4).

A2.5 Friction

Friction can be determined from data obtained in the accuracy test. It is the difference between the readings taken before and after the gauge is lightly tapped.

A2.6 Error, Position

The gauge shall be mounted in its normal calibrating position (see para. 3.4.3.10) and checked for accuracy in accordance with para. 6.2.3.1. The gauge shall then be placed in its intended operating position(s) and again checked for accuracy in accordance with para. 6.2.3.1. The difference between the two sets of readings is the position error.

A2.7 High Temperature Error

The gauge shall be tested for accuracy in accordance with para. 6.2.3.1. The gauge shall then be placed in a temperature test chamber at the manufacturer's rated maximum operating temperature and allowed to stabilize for a period of not less than 4 hr. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 6.2.3.1. The difference in readings at each test point between room temperature and the maximum operating temperature is the high temperature error.

A2.8 Low Temperature Error

The gauge shall be tested for accuracy in accordance with para. 6.2.3.1. The gauge shall then be

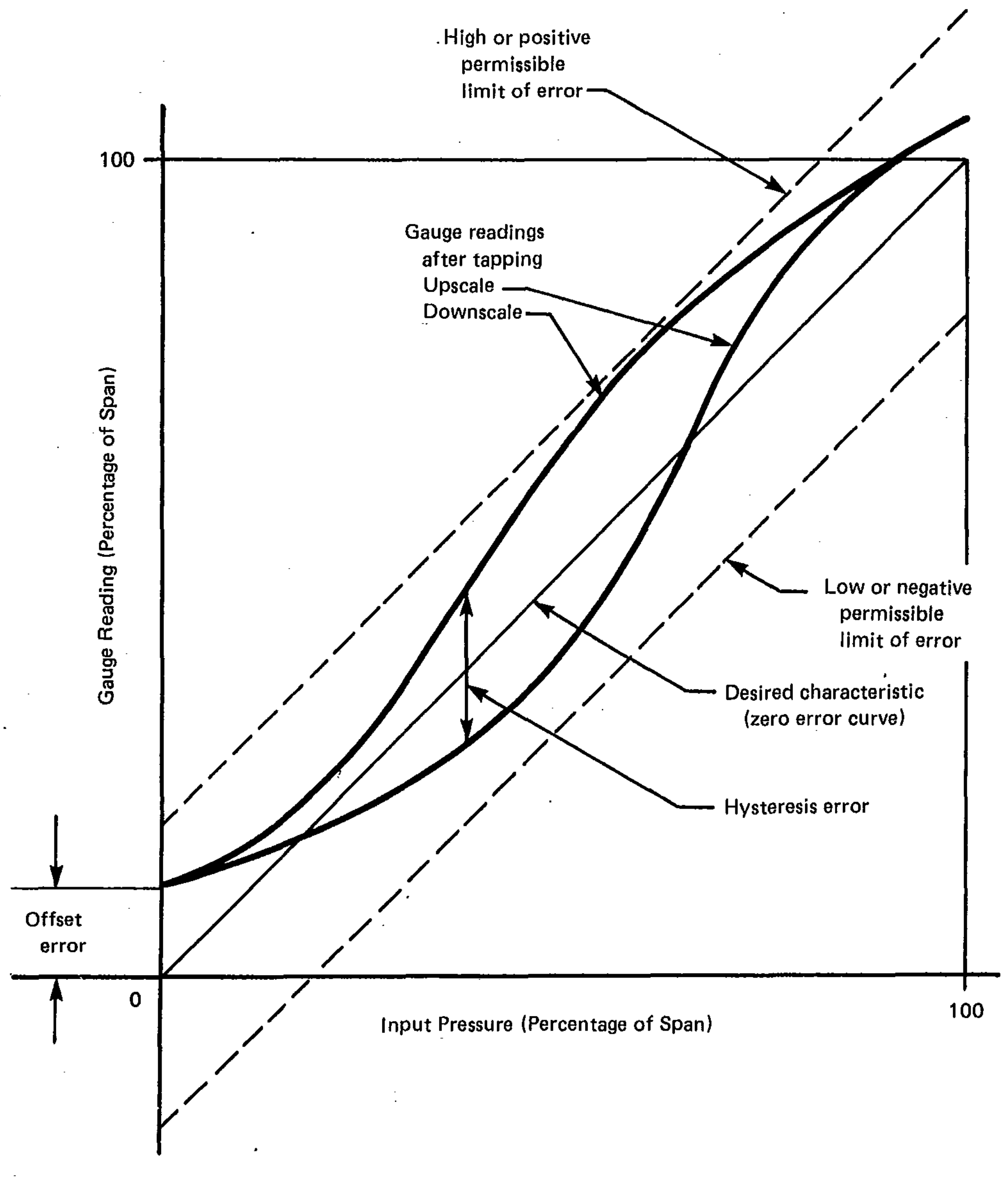


FIG. A1 HYSTERESIS AND OFFSET ERROR

placed in a temperature test chamber at the manufacturer's rated minimum operating temperature and allowed to stabilize for a period of not less than 4 hr. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 6.2.3.1. The difference in readings at each test point between room temperature and the minimum operating temperature is the low temperature error.

A2.9 Storage Temperature

The gauge shall be tested for accuracy in accordance with para. 6.2.3.1. The gauge shall then be placed in a temperature test chamber at the manufacturer's high limit of storage temperature for a period of 24 hr. The gauge shall then be placed in a temperature test chamber at the manufacturer's low limit of storage temperature for a period of 24 hr. This 48 hr cycle shall be repeated four times for a total of five complete cycles. The gauge shall then be allowed to stabilize at room temperature and then be checked for accuracy, in accordance with para. 6.2.3.1. The difference between the two accuracy tests is the effect of storage temperature expressed as a percentage of span.

A2.10 Vibration

A2.10.1 Vibration Tests. The gauge shall be tested for accuracy in accordance with para. 6.2.3.1 before starting the vibration tests. Each of the tests specified below shall be conducted separately in each of three mutually perpendicular axes. All tests in one axis shall be completed before proceeding to tests in another axis. The gauge under test shall be secured to the vibration table in the same manner that it will be secured in service. In the case of surface or flush mounting, the panel shall be sufficiently rigid to ensure that its motion will be essentially the same as the motion of the platform of the vibration machine. Input conditions should be monitored adjacent to the gauge mounting. A pressure of 50% ±5% of full scale shall be applied to the gauge under test during vibration. This pressure may be applied by pressurizing the gauge and sealing the pressure port.

A2.10.2 Exploratory Vibration Tests. To determine the presence of resonances, the gauge under test shall be vibrated at frequencies from 5 Hz to 60 Hz at a peak to peak amplitude not to exceed that shown in Table A1. The change in frequency shall be made in discrete frequency intervals of approximately 1 Hz and maintained at each frequency for about 15 sec. The frequencies and locations at which resonances occur shall be noted.

TABLE A1 VIBRATION TEST AMPLITUDES

Frequency Range, Hz	Peak to Peak Vibration Amplitude, in.
5 to 15	0.060+/−0.012
16 to 25	0.040+/−0.008
26 to 33	0.020+/−0.004
34 to 40	0.010+/−0.002
41 to 60	0.005+/−0.001

A2.10.3 Endurance Test. The gauge shall be tested for a period of 2 hr in each of three mutually perpendicular axes (6 hr total) at the resonant frequency. If more than one resonant frequency exists, the test shall be conducted at the highest resonant frequency. If no resonance is observed, the test shall be in accordance with Table A1. Test for accuracy in accordance with para. 6.2.3.1. The difference between the two accuracy tests is the effect of vibration expressed as a percent of span.

A2.11 Pressure, Proof

NOTE: This test is applicable only to new gauges and is not intended for gauges that have been fatigue tested or otherwise had their useful life reduced.

The gauge shall be tested for accuracy in accordance with para. 6.2.3.1. Apply proof pressure to the gauge under test and maintain for 1 min. Release pressure and allow gauge to stabilize. Test for accuracy in accordance with para. 6.2.3.1. The difference between the two accuracy tests is the effect of proof pressure expressed as a percentage of span.

NOTE: Proof pressure may be a semidestructive test and should not be conducted repeatedly on the same gauge.

A2.12 Pressure, Rupture

NOTE: This test is applicable only to new gauges and is not intended for gauges that have had their useful life reduced.

CAUTION: Select a reference gauge with a full scale pressure rating above the rupture pressure of the gauge under test to avoid damaging the reference gauge.

Apply pressure (hydraulic preferred) to the gauge under test, increasing at a rate not to exceed 20% of full scale per second of the gauge being tested. The pressure at which the pressure element assembly will no longer hold pressure is the rupture pressure.

A2.13 Fatigue

The gauge shall be tested for accuracy in accordance with para. 6.2.3.1. The gauge shall then be subjected to repeated applications of a pressure (hydraulic preferred) that produces an indication from 20% to 80% of the range of the gauge at a rate of 0.3 to 0.6 Hz (18 to 36 cpm). The application and release of the pressure shall be as smooth as practicable, so as not to subject the gauge mechanism to excessive upscale or downscale accelerations or high amplitude impulses (pressure spikes). The gauge shall be tested periodically for accuracy in accordance with the test specified in para. 6.2.3.1 not less than 1 hr after stopping the pressure cycling. The difference between the first set of readings at each test point and the latest set of readings at each test point is fatigue error at this point.

NOTE: Pressure limits different from 20% to 80% of the range of the gauge can have a significant effect on the fatigue error and fatigue life.

The gauge shall also be tested periodically for leakage of the pressure element assembly at full scale pressure. The fatigue life is the number of cycles to leakage.

A2.14 Liquid Filled Gauges – Seal Integrity and Stability

NOTE: This test must be conducted on each fill fluid.

(a) Mount gauge normally in accordance with the supplier's instruction.

(b) Heat filled gauge to the supplier's recommended maximum temperature and hold for a minimum of 2 hr.

(c) Reduce temperature to the supplier's recommended minimum temperature and hold for a minimum of 2 hr.

(d) Repeat the above cycle 20 times.

(e) No leakage of the fill fluid is permitted.

(f) The dial must remain readable. No discoloration of the fill fluid which degrades readability of the dial is permitted.

NOTE: If some slight discoloration is observed, additional exposure to the maximum temperature may be desirable, to determine whether further darkening of the fluid, to the point where readability is affected, will occur.

A2.15 Case – Slow Leak Test

NOTE: Applies only to sealed cases, without venting.

(a) Open Bourdon tube to allow gas to flow freely from the socket. Open socket hole to 1/8 in. diameter.

(b) For a liquid filled gauge – refill the case.

(c) With the gauge at 65°F/85°F, apply gas pressure to the socket, and slowly increase to allow case pressure to equal applied pressure at approximately 1 psi/sec. Record pressure required to activate relief mechanism.

(d) Case must relieve applied pressure without ejecting parts, other than the pressure relief device.

NOTE: Testing at higher or lower temperature may change results drastically. If gauge is to be used at other temperatures, test should be repeated at those temperatures. Supplier's temperature limit may not be exceeded.

APPENDIX B
GAUGES USED ON REGULATORS

(This Appendix is not an integral part of ASME B40.1-1991 and is included for information purposes only.)

This Appendix is intended to emphasize and supplement the recommendations contained in this Standard and to guide personnel specifying and installing gauges used on regulators for oxy-fuel gas welding, cutting, and allied processes. It should not be assumed that every test or safety procedure or method, precaution, equipment, or device is contained in this Appendix, or that abnormal or unusual circumstances may not warrant suggesting further requirements or additional procedures.

B1 SCOPE

This Appendix is intended to emphasize those parts of this Standard that are applicable to gauges commonly used on regulators for oxy-fuel gas welding, cutting, and allied processes and to provide specific considerations for gauge dial printing (marking) and gauge installation.

B2 RECOMMENDATIONS

B2.1 General References

Gauges used on regulators for oxy-fuel gas welding, cutting, and allied processes are to be governed by the recommendations of this Standard.

To facilitate the use of this Standard, references have been made to specific sections and paragraphs.

B2.2 General Contents

B2.2.1 Basic terms and definitions are outlined in section 2.

B2.2.2 General requirements are provided in section 3. Gauges used on regulators are usually size $1\frac{1}{2}$, 2, and $2\frac{1}{2}$, mounted by the stem (socket), and have open front cases with pressure relief. They shall be grade B accuracy or better.

B2.2.3 Safety considerations are discussed in section 4.

B2.2.4 Cleanliness levels are detailed in section 5. Gauges used on oxygen regulators shall have cleanliness equivalent to Level IV.

B2.2.5 Pressure gauge testing standards and procedures are discussed in section 6. Additional information is outlined in Appendix A.

B2.2.6 Section 7 contains helpful information relative to ordering gauges, related standards, and conversion factors.

B2.3 Gauges Used on Regulators

The following references to specific paragraphs of this Standard apply to gauges used on regulators. Appropriate additional considerations are discussed.

B2.3.1 Sizes. See para. 3.1. The nominal gauge sizes are $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ for regulator applications.

B2.3.2 Ranges. See para. 3.2. Common ranges for gauges used on regulators are listed in Table B1 by customary units and the corresponding SI units (rounded to a maximum of two significant figures).

It is recommended that no larger graduations than those shown in Table B1 be printed (marked) on the gauge dial. The spacing and displaying of the numerals marked on the gauge dial may vary for aesthetic reasons, provided that at least three numerals are displayed.

B2.3.3 Cases. See paras. 3.3.1 and 4.3.8. The cases commonly used for regulator gauge applications are open front with pressure relief. Figure 6 and paras. 3.3.1.1 and 3.3.1.4 outline case construction.

B2.3.4 Dials. See para. 3.3.2.

B2.3.4.1 Recommended units of measure for gauges used on regulators are kPa and psi (psig) presented together (dual scale).

TABLE B1 RANGES

Customary Units, psi			SI Units, kPa		
Range	Smallest Graduation	Numerals	Range	Smallest Graduation	Numerals
0/15	0.5	3.0	0/100	2.0	20
0/30	1.0	5.0	0/200	5.0	50
0/50	1.0	10	0/350	10	50
0/60	2.0	10	0/400	10	100
0/100	2.0	20	0/700	20	100
0/150	5.0	30	0/1 000	20	200
0/160	5.0	20	0/1 100	20	200
0/200	5.0	40	0/1 400	50	200
0/300	10	50	0/2 000	50	500
0/400	10	50	0/2 800	100	400
0/500	10	100	0/3 500	100	500
0/600	20	100	0/4 000	100	1 000
0/1,000	20	200	0/7 000	200	1 000
0/1,500	50	300	0/10 000	200	2 000
0/2,000	50	400	0/14 000	500	2 000
0/3,000	100	500	0/20 000	500	5 000
0/4,000	100	500	0/28 000	1000	4 000
0/5,000	100	1000	0/35 000	1000	5 000
0/6,000	200	1000	0/40 000	1000	10 000
0/7,500	200	1000	0/50 000	1000	10 000
0/10,000	200	2000	0/70 000	2000	10 000

B2.3.4.2 Paras. 3.3.2.3, 3.3.2.4, and 3.3.2.5 are applicable. Scale graduations on gauges installed on the output side of acetylene regulators are usually restricted to 15 psi, with the scale red-lined above 15 psi.

B2.3.4.3 Dials used on regulator gauges having ranges greater than 1000 psi usually contain a UL listing mark. The UL listing mark indicates that the gauge design complies with Underwriters Laboratories Safety Standard UL 404 and gauges bearing the listing mark are subject to UL followup procedures.

B2.3.5 Pointer Length. See para. 3.3.3.

B2.3.6 Pressure Connection. See para. 3.3.4. Gauges used on regulators are stem mounted and have $\frac{1}{8}$-27 NPT or $\frac{1}{4}$-18 NPT taper pipe threads, per ANSI/ASME B1.20.1.

B.2.3.7 Windows. See para. 3.3.7. Plastic windows are most commonly used on regulator gauges.

B.2.3.8 Accuracy. See para. 3.4. Gauges shall have an accuracy of Grade B or better (see Table 1). Applicable paragraphs in this section include: 3.4.1, 3.4.1.1, 3.4.1.2, 3.4.1.6, 3.4.1.9, 3.4.1.10, and 3.4.1.12.

B2.3.9 Safety. See section 4. Personnel specifying and installing pressure gauges used on oxy-fuel gas regulators should become familiar with the material presented in this section.

B2.3.10 Cleanliness. See section 5. Gauges used on oxygen regulators shall comply with cleanliness Level IV or better.

B2.3.11 Pressure Gauge Testing. See section 6. The pressure medium used for testing shall maintain the required cleanliness level of the gauge under calibration or calibration verification. The dead ended pressure element assembly of regulator gauges cannot be reliably cleaned once contaminated. Gauges contaminated with hydrocarbon pressure media shall not be used on oxygen regulators.

B3 INSTALLATION

B3.1 References

This section is limited to the installation of gauges on regulators, as used for oxy-fuel gas welding, cutting, and allied processes. The installation and operation of regulators may be found in manufacturer's

instruction manuals or handbooks, in the Occupational Safety and Health Standards for Industry (29 CFR, Part 1910), Subpart Q, and in the National Institute for Occupational Safety and Health (NIOSH), Safety and Health in Arc Welding and Gas Welding and Cutting.

B3.2 General Precautions

Oxygen and hydrocarbons (oil and grease are common hydrocarbons) under certain conditions can react violently, resulting in explosions, fire, and damage and injury to personnel and property. Never allow oil or grease to come into contact with any external or internal part of the threaded fitting or internal portion of the pressure element assembly of oxygen gauges. Even a minute amount of hydrocarbon can be hazardous in the presence of oxygen.

Regulator gauges should be installed or replaced only by skilled personnel who have been properly instructed.

B3.3 Installation Precautions

DO maintain the pressure element assembly and connection cleanliness level required for the intended application.

DO refer to the manufacturer's instruction manual for the correct pressure ranges to be used.

DO use the wrench flats provided on the gauge connection and the proper size wrench to secure the gauge to the regulator.

DO use only the thread sealant recommended by the regulator manufacturer for the specific application.

DO NOT install a low pressure gauge into the high pressure port on a regulator.

DO NOT use the gauge case for wrenching.

DO NOT interchange gauges from one gas application to another.

DO NOT exchange gauges from one regulator to another.

DO NOT conduct calibration verification using air from shop air lines, oil, or a contaminated pressure source.

DO NOT remove the restrictor installed in the gauge connection. The restrictor limits gas flow and aids in limiting temperature rise due to adiabatic compression.

B3.4 Operation Precautions

Gauges can fail during operation and the energy contained in compressed gases can produce violent effects should the pressure element assembly rupture.

DO always apply cylinder pressure slowly. Heat due to adiabatic compression can cause ignition.

DO use safety glasses or provide eye protection.

DO stand with the cylinder between yourself and the regulator (cylinder valve outlet facing away) when opening the cylinder valve.

DO read CGA Safety Bulletin SB-8, Use of Oxy-Fuel Gas Welding and Cutting Apparatus.

DO NOT stand in front of or behind the pressure gauges when applying cylinder pressure to the regulator. This will reduce the possibility of injury from flying parts should the pressure element assembly rupture.

DO NOT operate regulators without eye protection.

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